esa

the THIRD GHRSST-PP WORKSHOP

Users and Applications of High-Resolution Sea Surface Temperature Data Sets

Workshop Proceedings

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GHRSST-PP
GODAE High Resolution Sea Surface Temperature Pilot Project

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Foreword

Following the publication of the GHRSST-PP Strategy document in early 2002, significant progress towards implementing the GHRSST-PP was made during the Second GHRSST-PP Workshop (held at NASDA EOC, Tokyo, Japan, May 2002). So much, in fact, that the GHRSST-PP Science Team decided that a third workshop should take place at the end of 2002 in order to maintain the considerable momentum evident within the GHRSST-PP. The European Space Agency (ESA) kindly offered to host the workshop at the ESA/ESRIN facility in Frascati, Italy and I would like to take this opportunity to acknowledge the excellent support provided to the GHRSST-PP workshop organization committee by ESA. This volume provides a summary of the proceedings of the Third GHRSST-PP workshop which was attended by over 40 international participants with experience of SST data production, application, management and research.

The third GHRSST-PP workshop focused on ***Users and applications of high-resolution sea surface temperature data sets***. The aim of the workshop was to provide an opportunity for potential users to influence the data products and services that will be provided by the GHRSST-PP and provided a first formal opportunity for dialogue between many of the users of GHRSST-PP and the Science Team. Papers considering many aspects of real-time satellite derived sea surface temperature were presented emphasizing:

- The specific requirements for sea surface temperature data products by operational ocean coupled, and atmospheric models
- Applications of regional high resolution sea surface temperature data in real time
- Validation of satellite sea surface temperature data including inter-comparisons of satellite-satellite, satellite-in situ and, satellite-model output
- Merging and analysis of In situ sea surface temperature data together with Microwave, Infrared and other satellite measurements
- Operational schemes for the parameterization of SSTskin-SSTdepth SST and methods to account for diurnal warming

The workshop had a number of predefined target outputs. Keeping these in focus throughout the workshop was of paramount importance and I thank session leaders for their excellent coordination. In particular, the workshop has resulted in:

- A number of clearly defined, collaborative, application experiments in which GHRSST-PP data products will be operationally used during the 2003-2005 period.
- A set of Workshop recommendations for the implementation of the GHRSST-PP.
- A GHRSST-PPP implementation schedule in which responsibility for specific tasks is clearly identified.
- Recommendations for the operational optimal combination of satellite and in situ SST data sets.
- A consensus on the rules for conversion between SSTskin and SST depth measurements accounting for diurnal variability and the SSTskin-SSTdepth temperature difference.

The third GHRSST-PP workshop marked an important waypoint on the route to a successful implementation of the Pilot Project through direct interaction with the SST user community. The interest and enthusiasm for the project is immense and I would like to take this opportunity to thank all of the speakers and participants who made our time together in Italy extremely stimulating.

Craig Donlon
Chairman of the GHRSST-PP Science Team
Ispra, Italy, May 6th 2003.

Table of Contents

1 Introduction

The Global Ocean Data Assimilation Experiment (GODAE) high resolution sea surface temperature pilot project (GHRSST-PP) held its third international Workshop at the European Space Research Institute (ESRIN), Frascati, Italy, 2-4th December 2002. GODAE is an international project to develop operational ocean analysis and prediction systems for the global ocean. Through the period 2003-2007 GODAE aims to demonstrate the benefits and utility of global ocean products taking advantage of the enhanced data sampling that is expected in the middle of the current decade. One of the important dependencies is on sea surface temperature (SST) products that are required to properly constrain the upper ocean circulation and thermal structure. For GODAE, SST data products need to be available in near real time and have high spatial and temporal resolution. No such products exist today for the global domain. The aim of the GHRSST-PP is to address this need by developing and implementing a demonstration system that integrates data from complementary satellite instruments and in situ SST data sources using data fusion methods to provide an optimum SST field for use in global ocean modelling studies. A new generation of global, multi-sensor, high-resolution (better than 10 km and 12 hours) SST products will be generated, in near-real-time, for the benefit of the operational and scientific community during 2003-2006.

This workshop, sponsored by the European Space Agency, drew over 40 international Scientists working in operational centres, universities and research laboratories to discuss user requirements and the application of GHRSST-PP data products. It provided the first formal opportunity for dialogue between users of GHRSST-PP data products and the project Science Team and for users to influence the design and format of GHRSST-PP data products, discuss the application of GHRSST-PP data products and data provision services.

During the workshop, several discussions focussed on the generation of GHRSST-PP data products. The GHRSST-PP will bring together existing regional coverage satellite and in situ SST in real time at Regional Data Assembly Centres (RDAC). Three RDAC centres are currently in preparation; in the USA, Japan and Europe. GHRSST-PP will work closely with international data providers in mutually beneficial partnerships to ensure that data streams are exchanged and used in the most effective manner. It will maximize the benefits now offered by satellite microwave SST measurements, capable of providing daily global coverage of the entire ocean in cloud-free and cloudy areas (except in areas of heavy rainfall), with the higher radiometric fidelity and spatial resolution provided by both near-polar and geostationary orbit infrared satellite data streams in cloud-free areas. Each input data stream will be first quality controlled at the RDAC to produce GHRSST-PP Collated data products. Collated products consist of separate SST data streams that have already been calibrated, cleared of cloud and re-gridded to a common grid format. Collated data products will be accompanied by an error estimate for each grid point. These are then used to construct Merged SST data products sharing a common (global) grid format at 6-hourly intervals. Each Merged product grid cell will be accompanied with an error estimate based on schemes that utilise both objective and quantitative techniques. Merged data products represent the best available measurement data for different sensor types (satellite infrared, satellite microwave) for 6-hourly periods within each day. On a daily basis, all merged products will be used together with available quality-controlled in situ observations in an optimal-interpolation analysis procedure that will generate an estimate of the SST representing the subsurface SST (referred to as the foundation SST, SSTfnd, and similar to a "mixed-layer" temperature). The analysis procedures will have to account properly for diurnal warming and cool skin temperature signals because satellite observations obtained at different times of the day will include the diurnal cycle according to the phase and magnitude of the local diurnal signal. A separate "diurnal signal" data product will be provided with each GHRSST-PP analysed data product that allows users to utilize the diurnal signal component.

Several presentations focussed on the implementation model for GHRSST-PP, which is based on international collaboration implementing the processing and analysis tasks necessary to generate global-coverage SST data products in near-real-time. Regionally funded RDAC projects will produce regional (e.g., Atlantic Ocean) SST data products with an agreed format and a common processing system called the GHRSST-PP Data Processing specification (GDS). Regional data products will then be combined to provide global-coverage. GHRSST-PP global-coverage data products will be generated at a Global Data analysis Centre (GDAC) using RDAC data products together with additional global-coverage data streams that include areas not considered by the RDACs using an identical GDS to that of the RDAC. This implementation framework is referred to as regional/global task sharing. During the workshop, an initial set of GDS rules and methods were discussed and it was agreed that the GHRSST-PP will focus initially on the implementation of an operational capability demonstration system. The GSD will be upgraded to provide improved GHRSST-PP data products and services based on a continued program of research and development. A Data Product Computation Facility (DPCF) will be developed based on a large cluster computer system together with a modular code-base for global analysis of GHRSST-PP data products. Parallel runs of different data fusion and analysis procedures will be possible using the DPCF by GHRSST-PP investigators. Finally, a separate set of GHRSST-PP reanalysed data products will be produced in a delayed mode (> 70 days) that have a focus toward a long term archive of reference SST data products that can be used in climate related applications.

Given the many and varied SST data products that are available from various data centres through the Internet, it was clear from many presentations that the GHRSST-PP has a major role to play in terms of providing guidance, coordination and quality control procedures for SST data products and their application. A key issue focussed on the need for all GHRSST-PP data products to be accompanied by appropriate error statistics including a bias and root-mean-square error value for each product grid point. Several users expressed a desire for complete SST fields (analysed data products) while others preferred to use data products that provide the best available measurements rather than a data set that had been analysed to fill gaps in coverage (merged data products). Operational agencies stressed that timeliness and the secure delivery of data products were of paramount importance if GHRSST-PP data products were to be used successfully in an operational environment. Many groups represented at the workshop noted that they were now ready to use GHRSST-PP data products as soon as they become available and offered practical proposals as to how GHRSST-PP data products can be transitioned into operational use. A number of collaborative experiments were established, that will take place within the GHRSST-PP Applications and User Services (AUS) module dedicated to working in close collaboration with operational users. For example, GHRSST-PP data products will be used at several operational centres to quantify the impact of high resolution SST data products on their outputs. The feedback generated by these experiments will be used by the GHRSST-PP project to improve data products and services and aid in its transition from a demonstration system to an operational system in the coming years.

Building on the outcomes of the second GHRSST-PP workshop (held at the Earth Observation Research Centre, Tokyo in May 2002), that defined an implementation framework for the GHRSST-PP, a large component of the third workshop was dedicated to detailing how the GHRSST-PP is to be implemented. Many international groups (including data providers, space agencies, data management teams, operational agencies and scientific researchers) involved in the operational production and application of SST data products were represented at the third workshop and offered solutions and services for the implementation of the GHRSST-PP. Several projects are now actively engaged in the implementation of GHRSST-PP RDAC through nationally or regionally funded programs. Data access agreements are now in place for many data streams and others are in negotiation. Plans for a DPCF are currently in preparation that will be hosted at GHRSST-PP GDAC. Data product validation teams are now being convened and new SST data merging and fusion methodologies will soon be tested. Data management plans and a user information service (UIS) are in preparation, and an international project office will be opened in mid 2003.

Throughout the workshop a strong user requirement was expressed for high spatial and temporal resolution GHRSST-PP data products in many aspects ranging from operational ocean modelling, numerical weather forecasting, management and sustainability of marine resources, coastal monitoring programs, climate variability studies and data assimilation experiments, amongst others. The third GHRSST-PP workshop demonstrated that the GHRSST-PP is now a mature project with a clear user demand and marked an important waypoint on the route to its successful implementation. A complete description of the GHRSST-PP including all reference documentation can be found at http://www.ghrsst-pp.org. A publication of the workshop proceedings is now in preparation together with the GHRSST-PP Development and Implementation Plan (GDIP) that will be available on the GHRSST-PP project web site in due course. The next GHRSST-PP workshop will be hosted at the Jet Propulsion Laboratory, Pasadena CA, in the boreal autumn of 2003. For further information on the GHRSST-PP please contact any of the GHRSST-PP Science Team members via the project web page at http://www.ghrsst-pp.org.

2 Opening Session

2.1 Welcome and local arrangements

Craig Donlon (Chair) welcomed all participants and after thanking ESA for hosting the workshop, briefly introduced the facilities at ESA/ESRIN that were at the disposal of the participants. The Chair drew attention to changes in the Agenda.

the Chair stressed that several target outcomes should be borne in mind by all present throughout the workshop so that by the end of the workshop:

- A number of clearly defined, collaborative, application experiments in which GHRSST-PP data products will be operationally used and tested during the 2003-2005 period should be defined.
- A set of Workshop Recommendations for the implementation of the GHRSST-PP should be agreed.
- A detailed GHRSST-PP implementation schedule in which responsibility for specific tasks should be clearly identified.
- Recommendations for the operational optimal combination of satellite and in situ SST data sets should be in place.
- A consensus on the rules for conversion between SSTskin and SSTdepth measurements accounting for diurnal variability and the SSTskin-SSTdepth temperature difference should have been reached.

The Chair then introduced Dr Stephen Briggs to open the workshop.

2.2 Opening of the third GHRSST-PP workshop

Dr Stephen Briggs took the floor to officially welcome the workshop participants and to open the workshop. Briggs noted the importance of GHRSST-PP in the light to developments within the international community including CEOS and ESA. In particular, Briggs underlined that this is an important time for ESA with the launch of ENVISAT and the continuation of the ATSR series of radiometer. ESA was extremely pleased to be part of the GHRSSST-PP and GODAE/GCOS initiative. ESA has considerable experience with measuring SST from space and operates the ATSR series of satellite infrared radiometer. With the successful launch of ENVISAT, the high quality time series of global SST measurements would be continued for the immediate future. However, beyond AATSR, there are currently no European plans to fly a research imager for the measurement of SST.

Briggs stressed that in the coming years, ESA expects to make direct contributions to the GHRSST-PP through the AATSR program in order to further the application of AATSR SST data throughout the SST community. In particular, ESA is keen to see the development of a European RDAC within GHRSST-PP and has agreed to sponsor a project for this purpose called Medspiration. Briggs concluded noting that it was an extremely exciting time for SST research and development with microwave and infrared satellite imaging systems providing unprecedented coverage of the global ocean. The challenge for groups such as GHRSST-PP is to harness these data and apply them to the broadest set of applications. Briggs wished the participants a pleasant stay and the workshop to be a success.

2.3 Overview of the GHRSST-PP Implementation Plan

The Chair gave a general overview of the GHRSST-PP building on the 2nd GHRSST-PP workshop outcomes. Attention was focussed to why the GHRSST-PP is required using examples to remind the Workshop that the GHRSST-PP is a GODAE Pilot-Project contributing to the GODAE Common as part of the GODAE Measurement Network. Donlon recalled that the primary aim of GHRSST-PP is to:

- Oversee the development, timely delivery, assembly and processing of high-quality, global scale, SST products at a fine spatial and temporal resolution, for
- The diverse needs of GODAE,
- The scientific community,
- Operational users and,
- Climate applications.

In achieving this aim, the broad objective of the GHRSST-PP is to:

- Provide international focus and coordination for the sustained development and application of a new generation of global, high-resolution, SST products.

This objective was the focus of the Workshop in many ways. Several examples of why the GHRSST-PP was needed followed. These touched on the innovative observations now available from the TRMM TMI and AMSR microwave radiometer systems that are providing new insight into large scale systems such as the Madden-Julian Oscillation. The coverage of these particular sensors is unprecedented and the challenge is to derive maximum benefit from infrared and microwave polar orbiting senor data together with infrared geostationary systems. It was noted that there are significant issues outstanding in understanding the differences between complementary data sets in terms of (for example) cloud contamination and temporal/spatial differences. Furthermore, a distinct problem that the workshop must consider is the role of diurnal SST variability and the implications for merging data obtained at different times within a cycle. It was not clear how this particular problem would be tackled in an operational data processing framework. Touching on another issue, Donlon noted that error and confidence data must form part of the GHRSST-PP processing system and although there were options available for schemes pioneered by several groups, were these appropriate for the GHRSST-PP?

The Chair then moved to a short discussion on the application of GHRSST-PP data products noting that if an operational service was to become a sustainable entity, users from both the scientific and commercial sectors must be engaged at an early point in the project definition. The Chair urged all participants to consider the broadest possible user community throughout the discussions and to think of ways in which these groups can be actively engaged by the Pilot Project.

A short review of the basic implementation framework developed at the second GHRSST-PP workshop was then given (see Figure 2.3.1) drawing attention to the various project components including an overview of GHRSST-PP product definitions. It was noted that these were 'overdeveloped' and that a simplification was required – especially in terms of temporal resolution. The Chair reminded the workshop that attention should be focussed towards the applications and User Services and User information Services components of the GHRSST-PP implantation framework during this workshop.

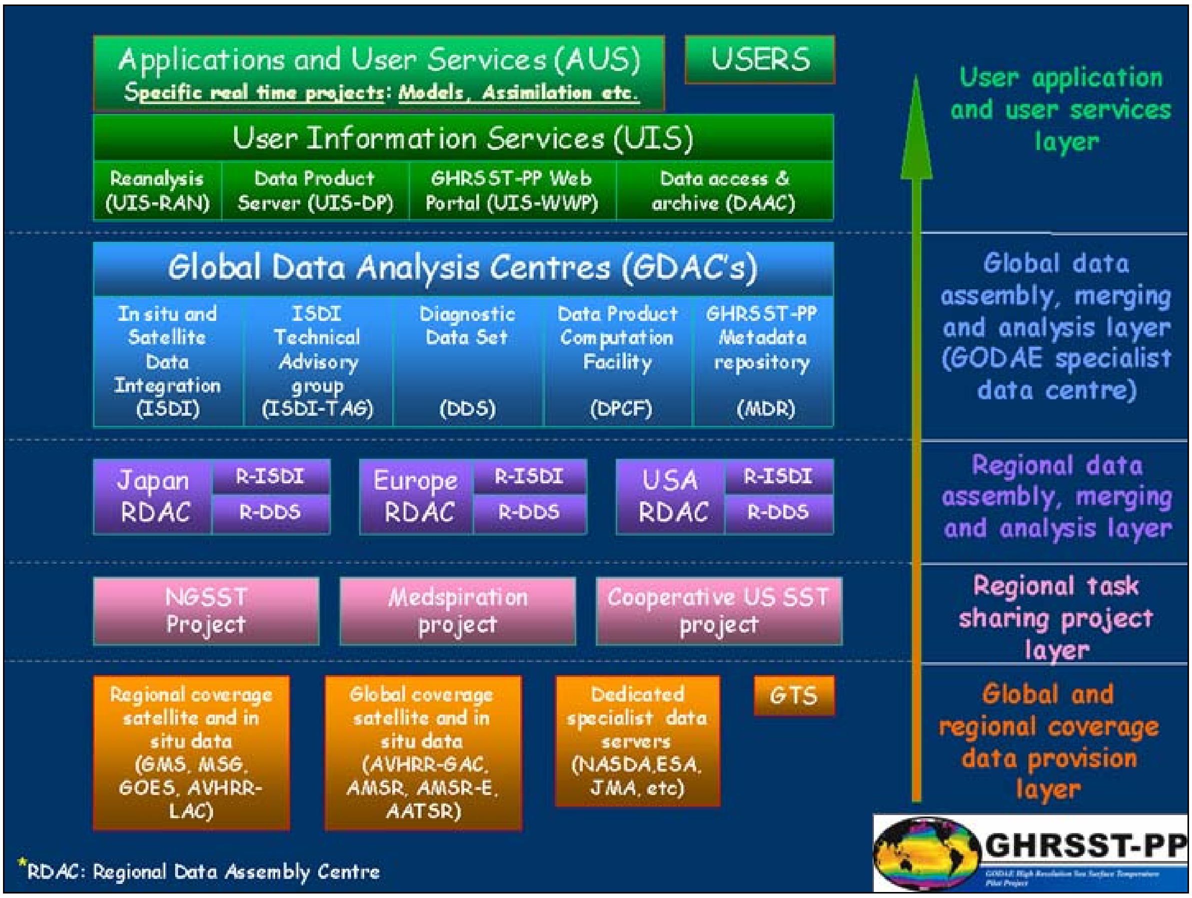


Figure 2.3.1 The general implementation framework developed fro the GHRSST-PP during the 2nd GHRSST-PP workshop, Tokyo, Japan.

Finally, the chair reminded the workshop that the GHRSST-PP was founded on a set of guiding statements. The GHRSST-PP will:

- Provide a new generation of operational SST products
- Address the needs of national and international projects (GODAE, GOOS, WOCE, CLIVAR, MERCATOR etc.)
- Ensure that duplication of international SST activities are minimized
- Synchronize data merging/processing procedures, techniques, algorithms and data formats,
- Develop and test an operationally efficient methodology for real time fusion of SST data
- Provide increased efficiency and cost-effectiveness of SST product generation and delivery
- Develop and foster considerable scientific and operational knowledge during the lifecycle of the GHRSST-PP
- Increase the network capacity within international and national projects of differing scope and budget

3 Session 1 GHRSST-PP Applications and User Services (AUS) December 2nd

This session, Chaired by Ian Robinson and Bill Emery, was dedicated a review of user requirements based on a number of key presentations from various user communities.

3.1 D. Llewellyn-Jones: Sea Surface Temperature Data for the detection of Global Change

Sea-surface temperature (SST) is a slowly varying geophysical parameter closely related to the rates of heat exchange between oceans and atmosphere. As such, it is an excellent parameter for the quantitative indication of change in the state of the global climate system. There are major challenges implied, these include not only the task of measuring SST with the necessary accuracy, coverage; and continuity; but also, when detecting and measuring change, that of distinguishing between natural variability and a trend in the state of the global climate. The observational requirements concerning accuracy, coverage and continuity will be discussed and identified.

The Along Track Scanning Radiometer (ATSR) series of satellite instrument has been designed for the detection of climate change having an accuracy requirement of better than 0,3K absolute. There are over 10 years of ATSR data now available for analysis from ATSR/1 and ATSR/2 and this is extended every day by the continued operation of the ATSR/2 and now the ENVISAT AATSR. Llewellyn-Jones stressed that the words of Stephen Briggs must be acted upon: if continuity of the unique data set now in hand in the shape of the ATSR is to be continued in order to make a significant statement about global warming, a follow on mission to the AATSR should be initiated immediately.

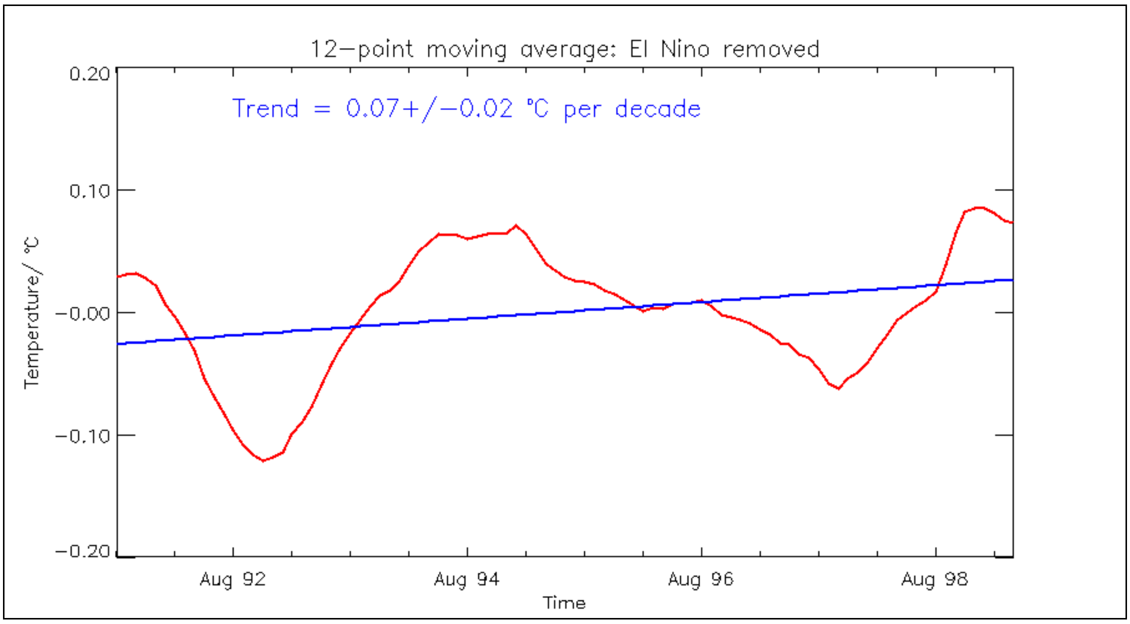


Figure 3.1.1 global mean SST derived from from clouod free ATSR 1 & 2 data 1991-1999 (S P Lawrence)

Preliminary analysis of the ATSR time series by S. Lawrence at the University of Leicester shows that a clear warming trend of 0.07decade^{-1} ±0.02Kcan be seen in monthly mean global ATSR SST values. The data used in this study used 0.5° Average SST (ASST) data from the ATSR1&2 that were averaged to 2.5° grids. Only data that always contained cloud free data were used in the analysis. Annual cycles and el Nino events have been removed. This is shown in Figure 3.1.1. The signal is dominated by cyclic behaviour due to the volcanic eruption of Mt Pinatubo releasing substantial aerosol into the atmosphere in

1992. A residual linear component shows increase in global temperature consistent with expectations and other observations 'Natural' variability dominates signal over10 years. Current work is focussed in improving the quality control procedures used to filter the ATSR data prior to the analysis.

Llewellyn-Jones considered the implications of a GHRSST-PP climate data set and noted that no single technique will provide all the SST information needed for a comprehensive climate SST data-set. There are particular demanding requirements for quality control procedures, coverage, continuity and, intelligent blending of different data-sets. Attention to detail in all of these aspects is essential if the data are to make an impact on climate research. Llewellyn-Jones then concluded by noting that GHRSST-PP should consider the following as critical areas fro climate related SST data sets:

- Effects of cloud-cover on climate signal needs attention
- How to deal with skin/bulk differences needs clarification
- Role of clouds in affecting satellite data-quality
- When introducing satellite data, the dependence , or otherwise, of retrieval methodology on *in situ* data needs to be appreciated

3.2 P. Bahurel: Application of GHRSST-PP data products in MERCATOR

Pierre Bauhrel described MERCATOR as a dedicated French 'agency' tasked with preparing an operational oceanography centre in Toulouse, France. It currently provides weekly ocean forecasts as a pre-operational activity (since January 2001) using one of the main operational ocean models within the European area. MErcator also develops the system as a distinct R&D effort. Key users of MERCATOR are in France (National oceanography and meteorology), Europe (EuroGOOS, MERSEA) and in the international area (GOOS and GODAE). The MERCATOR target system is an eddy resolving global coverage ocean model that has three distinct phases:

- 1/3° Atlantic Ocean Model (Complete)
- 1/15° Atlantic Ocean with a 2° global model (in progress)
- 1/15° Atlantic Ocean with a 1/4° global model (in progress)

The MERCATOR Ocean Bulletin, issued every Wednesday and freely available on http://www.mercator.com.fr, provides a full 4D description of the ocean including : Temperature, Salinity, Currents and Transports, Sea Surface Height, Mixed layer depth. It is a real-time service (Nowcast and 2-week forecast) that also operates in a hindcast mode (Reanalysis). The system routinely assimilates satellite altimetery, SST and in situ data (ARGO, T/S profiles, buoys). 8 regional area 'zoom' output data sets are generated covering the regions shown in Figure 3.2.1.

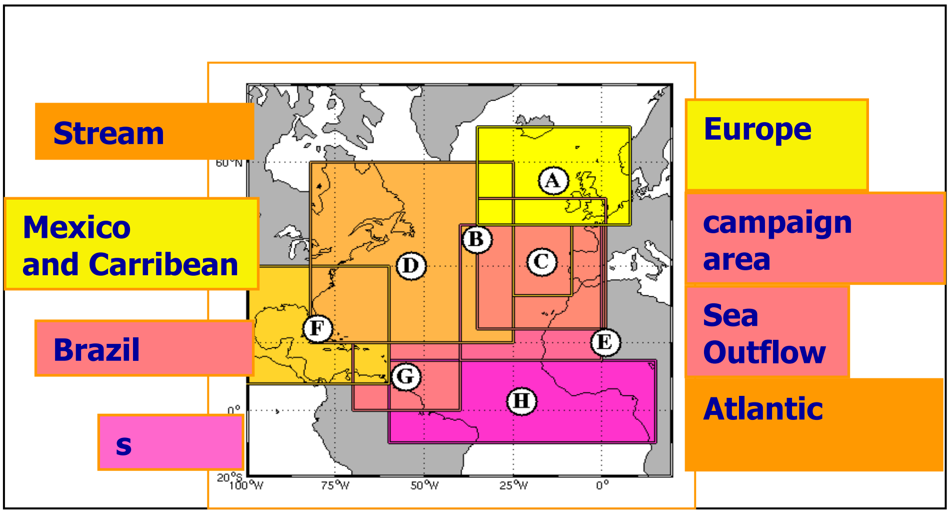


Figure 3.2.1 8 regional Zoom areas covered by the MERCATOR ocean bulletin. These data should be available via LAS server in the near future. (P. Bauhrel)

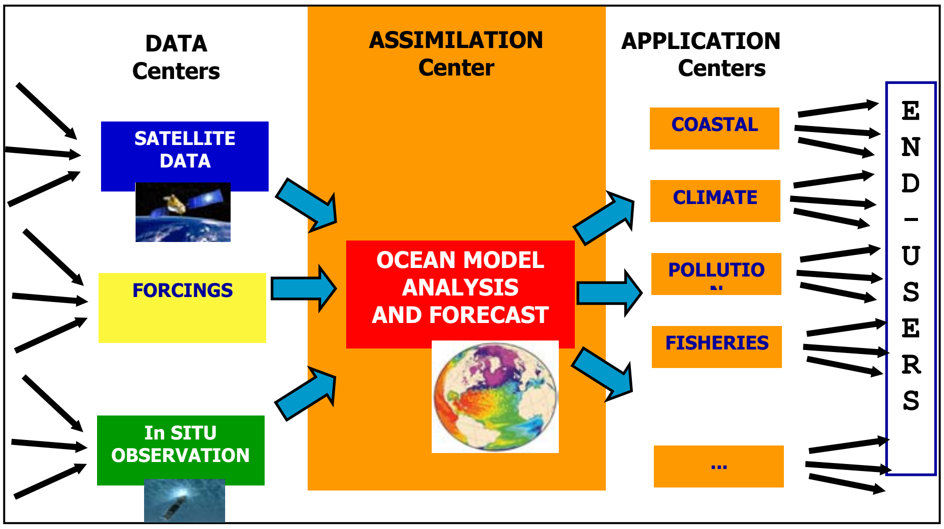


Figure 3.2.2 The position of the MERCATOR data assimilation centre with respect to data, applications and users (P. Bauhrel).

MERCATOR currently uses Reynolds SST in an operational relaxation procedure. Within the R&D effort associated with MERCATOR, collaboration with CMS Lannion is focussed on the use of high resolution SST data sets for use in assimilation procedures. Thus, MERCATOR has a keen interest in the GHRSST-PP and should be considered an important user of GHRSST-PP data products in terms of both application and R&D. Bauhrel provided several examples of MERCATOR output and drew attention to the fact that MERCATOR and GHRSST-PP share many common objectives in terms of users requirements and feedback.

Figure 3.2.2 summarises the data assimilation framework that is currently planned for the MERCATOR project. Bauhrel noted that once GHRSST-PP data products are made available, they would form a key data input into the assimilation scheme following a testing period. Finally, it was clear that MERCATOR could make immediate use of GHRSST-PP data products including SSTdepth and SSTskin measurements. MERCATOR requires a near real time global satellite SST product with resolution of at least 10 km (i.e. a high space and time resolution). The satellite SST product should be validated against in-situ data and in-situ data should be used to correct for large scale biases in satellite estimates.

3.3 H. Cattle: CLIVAR and the GHRSST-PP

Howard Cattle, Director of the climate Variability (CLIVAR) Project Office, provided an overview of the CLIVAR (Climate Variability) project with particular emphasis on the SST data sets that CLIVAR requires to fulfil its aim. Cattle discussed the objective of CLIVAR which is to:

"determine to what extent climate can be predicted and the extent of human influence on climate, aiming at the goal of greatly improved understanding of the role of climate in the total earth system".

He noted that CLIVAR is part of the World Climate Research Program (WCRP) family of projects that includes:

- [Tropical Ocean-Global Atmosphere (TOGA)]
- World Ocean Circulation Experiment (WOCE)
- Global Water and Energy Experiment (GEWEX)
- Stratospheric Processes and Climate (SPARC)
- Arctic Climate System Study (ACSYS)
- Cryosphere and Climate (CliC)
- Carbon Cycle, Water and Food and Fibre Projects (joint with IGBP/IHDP)

Cattle noted that the SST requirements of CLIVAR are based on a need to describe and understand the physical processes responsible for climate variability and predictability at a variety of timescales. This should be done through the collection and analysis of observations and the development and application of models of the coupled climate system, in cooperation with other relevant climate-research and observing programmes. In this sense, links between GHRSST-PP and CLIVAR are important. Of critical importance to the CLIVAR community is the need for climate quality data and so the GHRSST-PP Reanalysis project was a particularly important and very welcome component of the GHRSST-PP. CLIVAR is developing activity on for a global ocean reanalysis and GODAE (and thus GHRSST-PP) is a key demonstrator for this activity.. However, CLIVAR needs to develop a dialogue with GODAE to identify the R&D needed to develop the ocean re-analysis concept. This does offer an extension of GHRSST beyond its pilot phase (forwards and backwards in time) that is highly desirable.

GHRSST and GODAE more generally have the potential to provide key input into developing techniques of coupled model analyses. CLIVAR has several scientific steering groups, working groups and panels that include the following:

Panels:

- Atlantic, Pacific and Southern Ocean Basin Panels
- CLIVAR Ocean Observations Panel
- American and Asian-Australian Monsoon Panels
- Variability of the African Climate System Panel
- PAGES/CIIVAR Panel

Working Groups:

- Working Group on Coupled Modelling (jointly with the Joint Scientific Committee for WCRP)
- Working Group on Seasonal to Inter-annual Prediction
- Expert Team on Climate Change Detection (with CCI)

These groups are focussed on the main research areas of the CLIVAR project as shown in Figure 3.3.1.

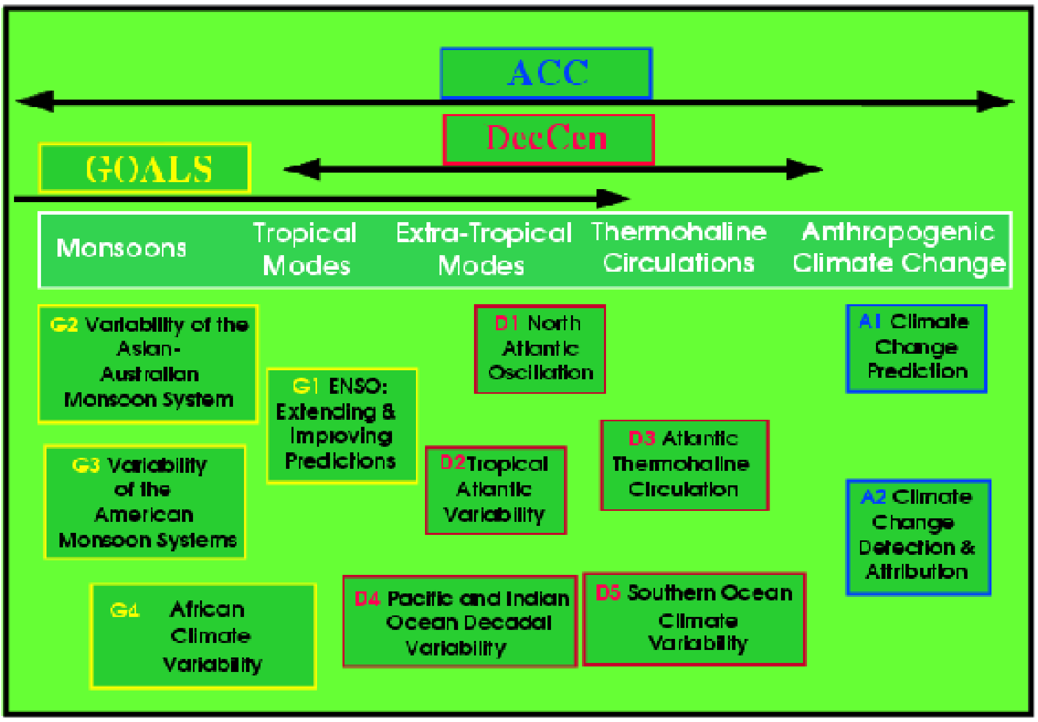


Figure 3.3.1. the Principal research areas of CLIVAR. (H. Cattle).

These groups/research areas have different SST data requirements that are not all clearly defined. However, the CLIVAR Southern Ocean Panel (SOP) have specifically endorsed the GHRSST project (SOP1, Hobart, March 2002) emphasising the particular usefulness of multiple sensors in the cloudy Southern Ocean. The SOP seeks guidance on right mix of *in situ* measurements needed to complement and remove biases from satellite measurements for their own work and to ensure GHRSST-PP goals are met in the Southern Ocean.

Based on the CLIVAR Initial Implementation Plan (1998), CLIVAR notes that "*Global sea surface temperature (SST) analyses are considered fundamental and essential to progress in CLIVAR*." In addition, "*SST is important for virtually all the CLIVAR Principal Research Areas*" and "*In general the required SST signal becomes smaller and of larger scale as we go from GOALS activities to those of ACC*.". In practice, CLIVAR requires SST data sets for the following priority activities:

- Climate change detection (requirement for long consistent times series)
- Validation of coupled atmosphere-ocean models
- Input to seasonal and inter-annual prediction models (ENSO, monsoon …)
- Exploring decadal timescale variability and its prediction
- Forcing and validation of global (and regional) ocean models
- A variety of global scale empirical, analytical and diagnostic studies
- Climate monitoring

Within these activities, the following SST data requirements have been specified (CLIVAR Implementation Plan, 1998):

- In support of NWP which will supply global stress and heat flux estimates for CLIVAR: 0.2-0.5°C on 100 km square x 1 day resolution.

- For ENSO prediction: 0.2-0.3°C on 200 x 30-100km x 5 days in the tropics. Bias requirement is more severe in the convective regions; less severe in the central to eastern Pacific.
- For climate change detection: 0.1°C on 200-500 km square x monthly.

In addition, CLIVAR may require resolution of the diurnal cycle for some applications and improved accuracy in the tropics (0.1°C).

Finally, Cattle summarized some of the applications for GHRSST-PP data products within the CLIVAR project. These included:

- Validation of high resolution ocean coupled models and forcing/validation of high resolution ocean models.
- Studies and monitoring of western boundary currents and other high SST
- Wider climate monitoring (including ENSO, monsoons, NAO etc.)
- Seasonal to inter-annual prediction studies using global and regional models.
- Together with GODAE itself, as input to ocean reanalysis efforts.
- Exploration of high resolution ocean coupled model analysis techniques.
- Development of surface flux datasets (links to IGBP SOLAS)

Ian Robinson was interested to know how CLIVAR requirements will mature as the 1998 Implementation plan may be out of date. Cattle responded that there was a need for a clearer picture of the SST data requirements within CLIVAR (prompted during the preparation for this meeting). However, this had implications in terms of data management within CLIVAR and beyond. Cattle concluded that these were issues that would be discussed in the following year.

3.4 P. Yves-Le Traon: Applications of GHRSST-PP data products in MERSEA

Pierre Le Traon began by reminding the workshop that GODAE has a very focussed set of objectives:

"To provide a practical demonstration of real-time operational global oceanography with:

- *Regular comprehensive description of the ocean circulation at high temporal and spatial resolution, and,*
- *Consistent with a suite of remote and in-situ measurements and appropriate dynamical and physical constraints."*

GODAE beneficiaries include climate and seasonal forecasting, marine safety, fisheries, the offshore industry, Navy applications and management of shelf/coastal areas. The integrated description of the ocean that GODAE will provide will also be highly beneficial to the research community GODAE includes many of the main oceanographic operational and research institutions from Australia, Japan, United States, United Kingdom, France, Norway, Europe. European partners (FOAM, MERCATOR, TOPAZ, MFS).

LeTraon noted that the EU MERSEA project was a collection of European partners (FOAM, MERCATOR, TOPAZ, MFS) 'building EU' GODAE. Currently, the MERSEA STRAND-1 project "Building the European contribution to GODAE" has a primary objective to integrate existing space/in-situ observations through ocean modelling and data assimilation systems in order to:

- deliver information products (biological and physical) such as needed by users concerned with European marine environment and security policies (EU Global Monitoring for Environment and Security, GMES);
- report on deficiencies of the monitoring system and the problems met and lessons learnt in supplying the information products;
- contribute to improve knowledge, methods and tools required for monitoring, information production and delivery for marine environment and security.

MERSEA strand-1 is an 18 month project that will be followed up by a larger 'Integrated project in 2003/4 (proposals in preparation).

Le Traon then discussed the use of SST data in ocean models concluding that the main role of SST data relaxation providing a mechanism to correct for forcing errors. The SST has a considerable impact on the subsurface temperature field as shown in Figure 3.4.1.

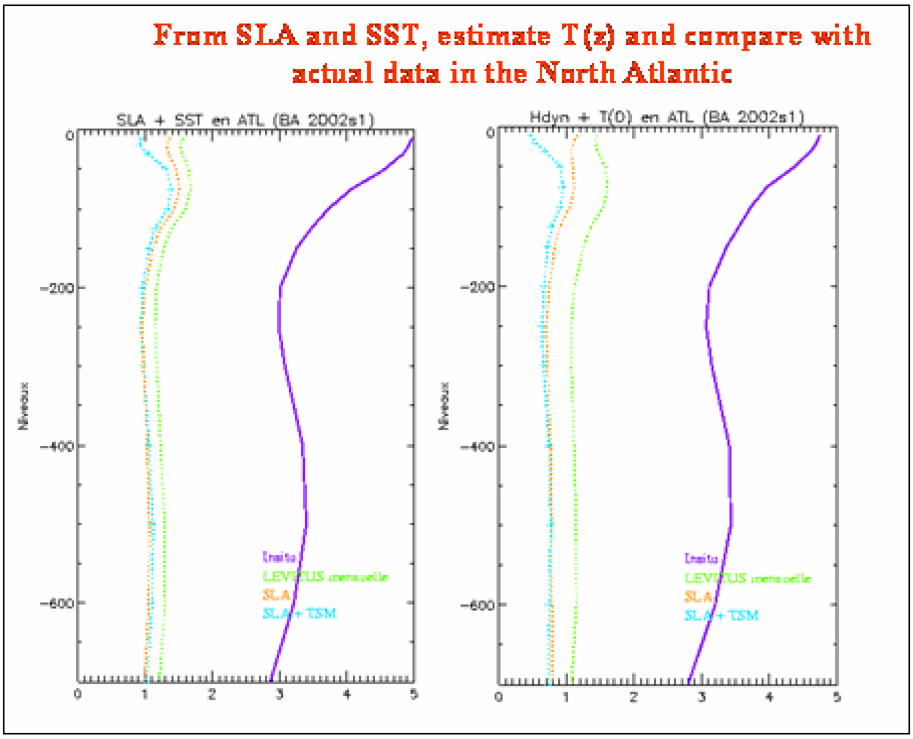


Figure 3.4.1 the impact of SST and SLA data on the estimation of subsurface parameters using a simple regression methods MERCATOR/ARMOR. (P. Yves-LeTraon).

SST observations also give information on ocean dynamics (eddies, fronts) and this information should be used in an assimilation system. Accordingly, in the future, SST should be directly assimilated (multivariate OI, Kalman, Adjoint) (GODAE) providing impact on ocean dynamics and deep fields.

Le Traon noted that the main SST requirements for MERSEA today are:

- daily SST with a resolution < 10 km + error estimates
- analyzed product (i.e. with no gaps) useful mainly for relaxation methods and for validation
- "merged" products (i.e. best SST observation, no (cloud) gap filling) will be more likely used for advanced data assimilation techniques. Errors needed.

- diurnal cycle not resolved by most modelling/assimilation systems. Use of SST data corrected for these effects. Use of bulk SST (first model level depth is a few meters).

These data will be used for

- Sensitivity/Impact experiments: Analyze the impact of new products on existing assimilation systems
- parallel experiment where only the SST data are modified
- analyze impact on ocean analyses and forecasts (validation tools, comparison with external data sets) (internal metrics)
- analyze impact on applications/users (external metrics).

Through these activities, MERSEA can help GHRSST-PP with feedback from modelling/assimilation systems helping to generate better analyses of SST.

3.5 R. Santoleri: Mediterranean Forecasting System: results and prospective of satellite sea surface temperature assimilation

The Mediterranean Forecasting System (MFS) has two major goals. From a scientific point of view, it is intended to explore, model and quantify the potential predictability of the ecosystem fluctuations at the level of primary producers from the overall basin scale to the coastal/shelf areas and for the time scales of weeks to months, through the development and implementation of an automatic monitoring and a now-casting/forecasting modelling system, the latter called the Mediterranean ocean Forecasting System (MFS). In addition, it aims to demonstrate the feasibility of a Mediterranean basin operational system for predictions of currents and biochemical parameters in the overall basin and coastal/shelf areas and to develop interfaces to user communities for dissemination of forecast results.

During the first phase of MFS (MFS Pilot Project-MFSPP), which focused on the implementation of the observing system backbone (both satellite and in situ data) and on the demonstration of forecasting capabilities at basin scale, a near real time acquisition and processing system of remote sensing data was set up and tested for the Mediterranean sea. The system, shown schematically in Figure 3.5.1, was based on existing facilities and could serve as a prototype also for future operational systems.

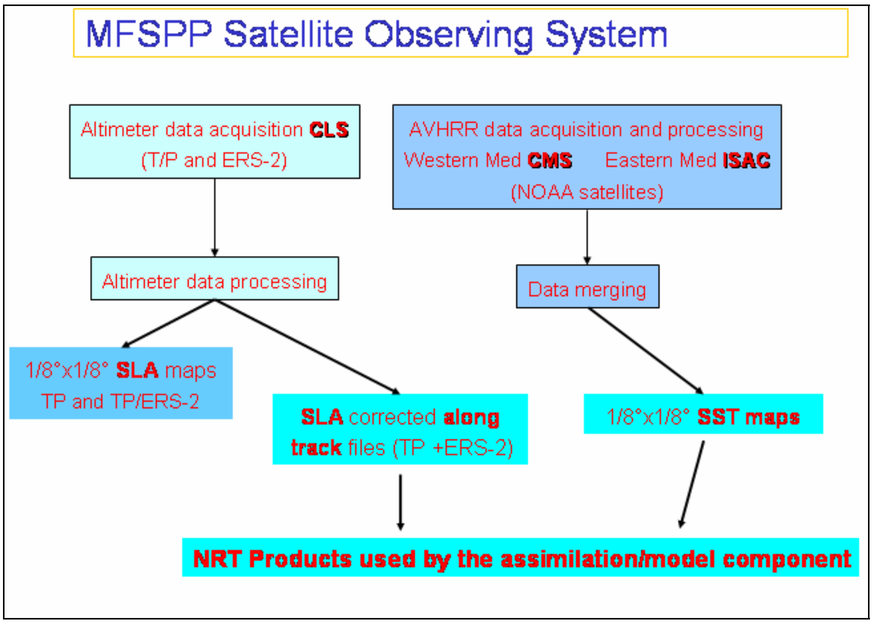


Figure 3.5.1 Schematic overview of the MFSPP Satellite observing system (L. Santoleri)

Near real time (NRT) remote sensing data (AVHRR, TOPEX/Poseidon and ERS-2) coupled with in situ VOS-XBT temperature profiles provided the basic data sets for the weekly production of nowcasts. The forecast is then initialized every week from such optimal estimate of the basin scale circulation. This observing/forecasting system started in January 2000 of and it is still operational, providing the weekly analyses and forecasts on the web.

The development of a NRT Sea Surface Temperature product for MFSPP was a fundamental step in the definition of the operational satellite system in support of predictions. The SST data products use AVHRR data that are mapped by optimal interpolation to the model grid and provided to the MFSPP community for data assimilation where weekly/10 day products are used in a heat flux correction (nudging) procedure.

MFSPP utilizes several regional models at a resolution of 5 km and ultra high resolution models at 1.5-2km resolution as shown in Figure 3.5.2. A new ocean forecasting project based in the Adriatic, uses nested models with resolutions of 5,1.5 and 0.5 km. For this project, daily composite AVHRR SST maps are generated as scaled gif format maps mapped to the model grid and made available via http transport. Cloud clearing is performed using both automatic and operator control procedures as an automatic system alone is not robust enough to assure high quality data without the loss of an unacceptable number of cloud free pixels.

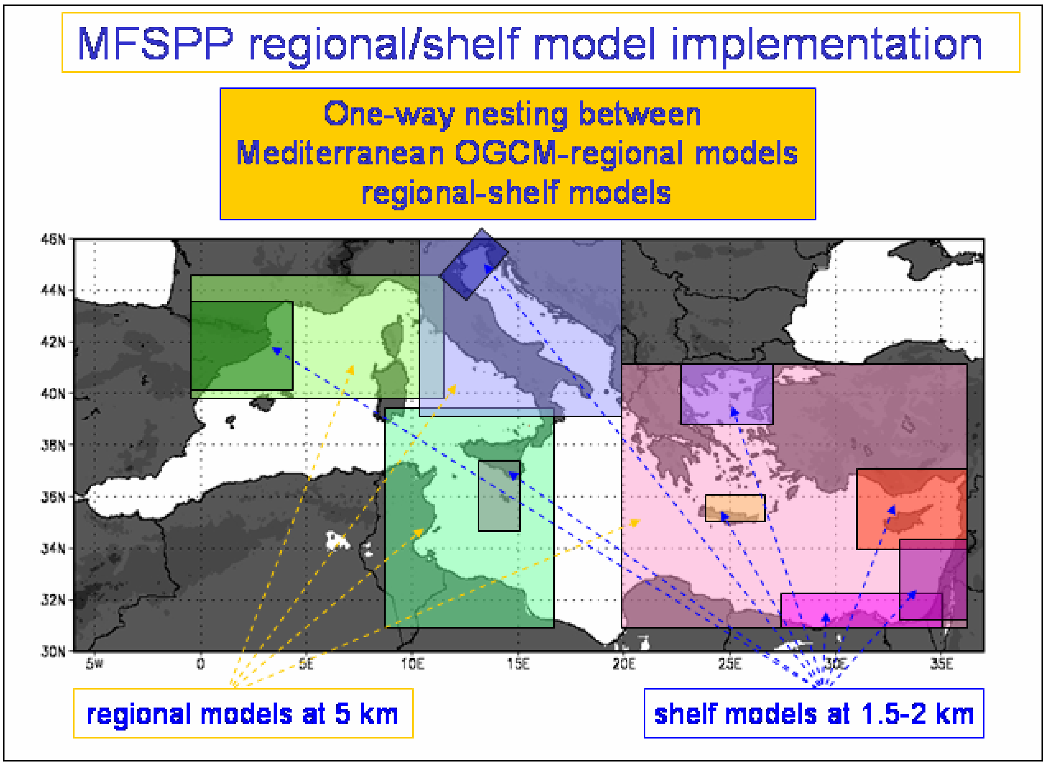


Figure 3.5.2 MFSPP regional/shelf model implementation

In developing ocean forecasting systems, it is important to establish the reliability and accuracy of the observations used. As a consequence, there is a need to quantify the quality of NRT SST products against delayed mode high quality products. The results of this analysis provided a guidance for the improvement of sea surface temperature products to be used in the next phase of the MFS project, called MFSTEP. During MFSTEP, 1/16° resolution models of the Mediterranean basin will be developed with 3km and 1.5 km nested models over shelf and coastal regions providing weekly forecasts. The GHRSST-PP data streams (having a spatial resolution of 10 km) will not be sufficient for these models.

3.6 W. Emery: Using GHRSST-PP data products in Maximum Cross Correlation (MCC) ocean current mapping

Ocean surface circulation can be estimated by automated tracking of thermal infrared features in pairs of sequential satellite imagery. A seven year time series of velocity, extracted from thermal imagery of the East Australian Current using the Maximum Cross Correlation (MCC) technique, provides enough measurements for a more statistical evaluation of the method than has previously been possible. Excluding one year with extensive cloud cover, the method produces about 8,000 velocity estimates per month with some seasonal variation. Method precision is estimated to be between 0.08 and 0.2 ms-1 rms, the lower value with more restrictive image compositing.

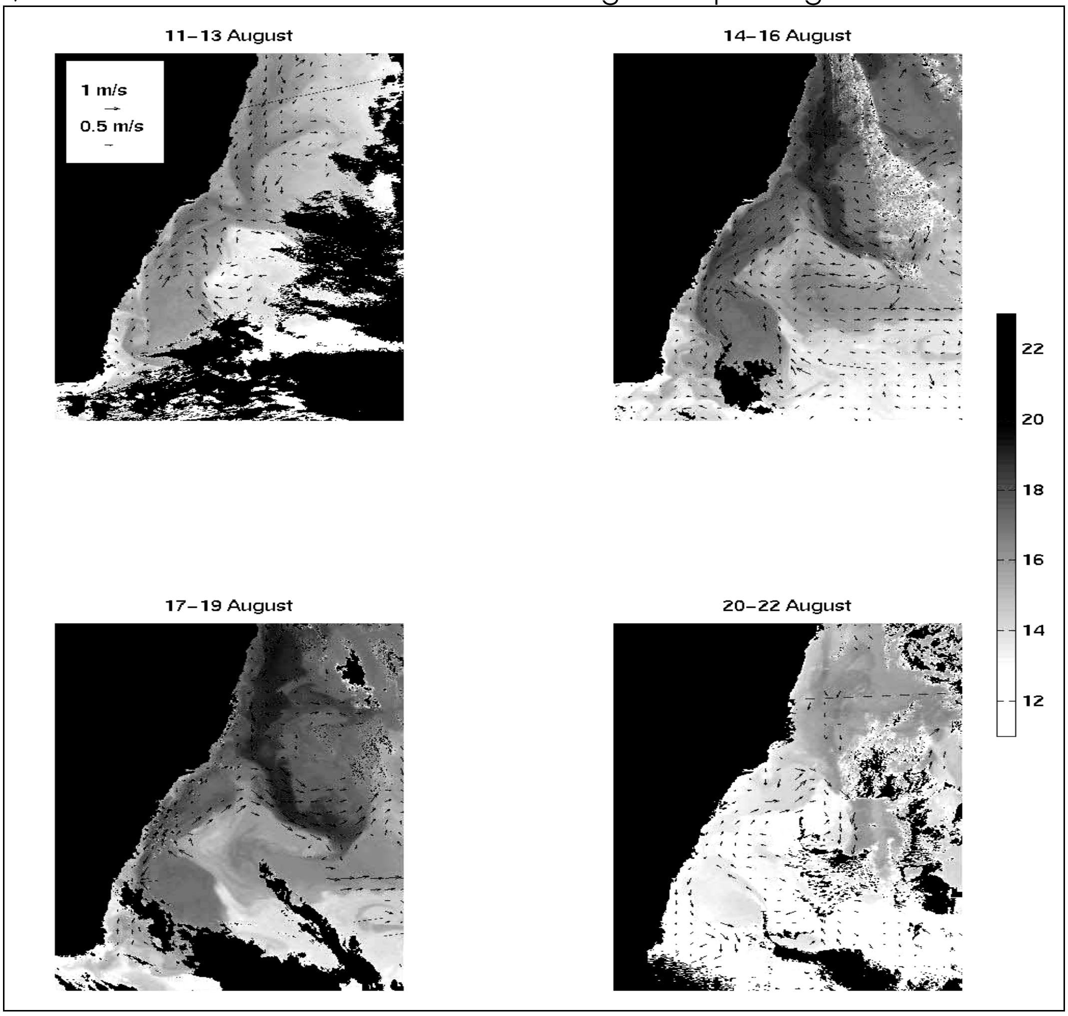


Figure 3.6.1 Example MCC 3 day composite surface vector currents (computed from sequential image pairs) plotted over SST maps derived from the AVHRR. (B. Emery)

Mean flow, time-dependent flow, and eddy kinetic energy from the time series compare favorably with values derived from a dynamic height climatology, altimeter analyses, and drifter data sets in the region. The observations reproduce similar features in the flow. The differences between the observations in relation to noise in the methods and differences in the types of velocities they measure are important. An optimum interpolation method has now been introduced whereby the MCC currents can be merged with geostrophic surface currents computed from along-track altimetry. Taken together these satellite data sets offer a significant improvement in our description of the East Australian Current region and its variability in time and space. An example of typical output generated by the MCC technique is presented in Figure 3.6.1. Emery concluded that SST data from the GHRSST-PP were not optimised for application of the MCC technique which appears to work best with brightness temperature data. However, within the GHRSST-PP there may be scope to use brightness temperature data and the MCC in some Diagnostic data set areas.

3.7 H. Kawamura: The Coastal Ocean Observing Panel (COOP) and GHRSST-PP

The Global Ocean Observing System (GOOS) Coastal Ocean Observation Panel (COOP) was established in 2000 and includes experts in ocean observations. Although the ocean phenomena of interest tend to be local in scale, they occur in coastal waters world-wide and are a consequence of regional to global scale forcing. Furthermore, phenomena that are priorities in one region are often not priorities in other regions (e.g., detecting and predicting the movement of sea ice is not a priority in the coastal waters of the western tropical Pacific Ocean). Thus, the coastal module is conceived as a global federation in which national and regional observing systems (GOOS Regional Associations, GRAs) are nested in a Global Coastal System (the GCS). The GCS will measure and process a common set of variables that are required to detect or predict most of the phenomena of interest. GRAs will benefit from and contribute to the GCS. Depending on national and regional priorities, GRAs will increase the resolution at which common variables are measured, supplement common variables with additional variables, and provide data and information that are tailored to the requirements of national and regional stakeholders.

The GCS, which is the focus of the COOP design plan, will

(1) establish a relatively sparse network of reference and sentinel stations;
(2) provide economies of scale that will improve the cost-effectiveness of national and regional observing system by investing in a global system that minimizes redundancy and optimizes data and information exchange;
(3) formulate and institute international standards and protocols for measurements, data dissemination and management;
(4) link the coastal federation of observing systems to the global ocean module of GOOS, and the Global Terrestrial Observing System (GTOS);
(5) provide the means for comparative ecosystem analysis required to understand and predict variability on the local scale of interest; and
(6) facilitate capacity building.

The GHRSST-PP is a potential contributor to both the design and implementation of the COOP (see the draft COOP Strategic design plan http://ioc.unesco.org/goos/COOP-4/coop4.htm). The areas of particular interest for GHRSST-PP are:

- The Initial Subsystem for Coastal Observations where SST is one of the key parameters.
- Combining Observations and Models
- Data Management and Communications Subsystem

GHRSST-PP is specifically mentioned as a "potential building block" of the COOP Coastal Module operational systems within an integrated framework as suggested by Figure 3.7.1.

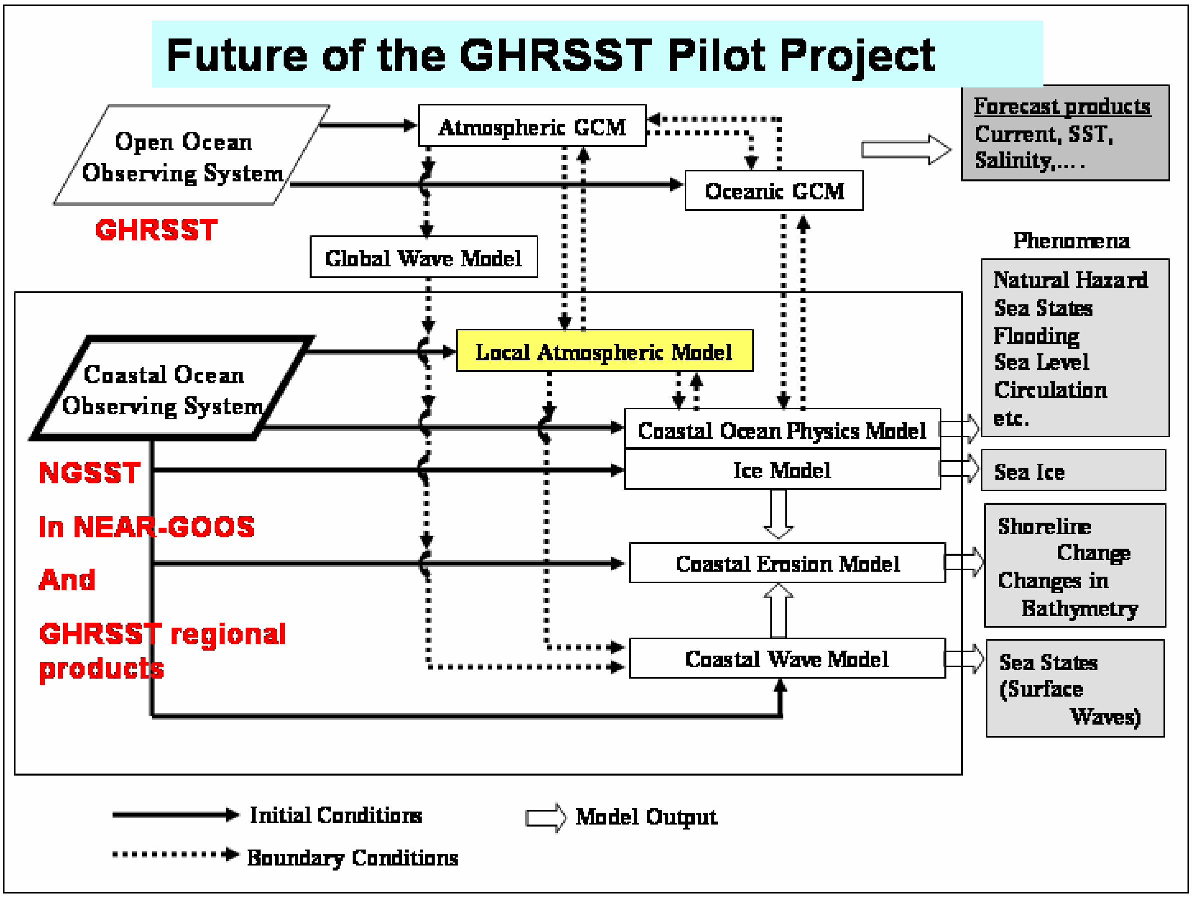


Figure 3.7.1 Potential role of GHRSST-PP in the development of COOP and GOOS activities.

Kawamura noted that the COOP demanded very high resolution data products that are far beyond the specifications of the GHRSST-PP. For example, the NEAR-GOOS goups are developing high resolution, cloud-free, quality-controlled SST1m (tuned for the region) products through cooperation with Chinese, Korean and Russian Scientists. The spatial resolution of these products will be -km and a temporal resolution of 3-hours. Coverage will be over the NEAR-GOOS region including the Japan Sea, Yellow Sea and East China Sea. Collaboration with the NEAR-GOOS II operational oceanography project and linkage to the GODAE High Resolution SST project will be maintained throughout this project.

Kawamura concluded that GHRSST-PP will best serve the COOP with relatively coarse resolution SST data that the coop can 'nest' ultra high resolution data within when this is available.

3.8 M. Drusch: Requirements for future SST data sets from the ECMWF perspective

ECMWF's activities are centred on: 1) Ten-day medium-range weather forecasts, 2) Seasonal forecasts and 3) Re-Analysis projects, e.g. ERA40. Although the quality of the forecasts and the re-analysis data heavily relies on the SST analysis, each group has its specific needs with regards to accuracy, timeliness and heritage. These dare reviewed below.

Medium-range Forecasts: The SST analysis defines the lower boundary condition for the atmospheric model. In addition, it is a crucial parameter in the satellite data assimilation scheme, since the SST has a significant impact on the quality control in the microwave atmospheric window channels. Therefore, it would be most beneficial if skin and bulk temperature would be available at high resolutions. For the atmospheric model, a real time daily product is an essential requirement, but the refresh frequency of parts of data can be of order 2-3 days. The model and data assimilation also require the specification of lake temperatures. The SST product should not be confined to the ocean and a few large lakes, but should cover all water bodies. Finally an associated field of sea ice fractional cover, consistent with the SST data will be needed at the resolution of the SST data.

The accuracy for the bulk temperature should be better than 0.2 K at a minimum resolution of 0.5° x 0.5°. In order to perform a reliable quality check in the satellite data assimilation step, the microwave surface emission (emissivity x SST) has to be known with an accuracy of 0.5 K. Consequently, the error of the skin temperature should not exceed this value on the 10 x 10 km^2 scale. Information on the diurnal cycle would be useful for time collocation of satellite observations and the SST analysis.

Seasonal Forecasts: An accurate description of the bulk temperature has been defined as the major target. On a 1° x 1° grid an absolute accuracy of 0.1 K would be most desirable. For an operational phase, multi-year records are required, during which no systematic changes will be made or (if so) re-analysis products will be released. Daily and weekly products should be available in near- real time, e.g. with a 2-3 day maximum delay.

Re-Analysis: The parameter of interest is again the bulk temperature on a 1° x 1° grid with an absolute accuracy of 0.1 K. In order to start working with the data at least a one-year data set had to be available on a daily basis. For future applications even higher temporal resolution would be desirable to resolve the diurnal cycle of the SST. One major task in Re-Analysis applications is the reconstruction of past data sets using the latest technology. Therefore, it should be considered if current SST data sets could be reprocessed within the framework of GHRSST using the new GHRSST products.

Demonstration Projects: During the pre-operational phase two types of demonstration projects could be defined. In order to access the impact of a new GHRSST-PP SST analysis the Integrated Forecast System could be used to run medium-range forecasts for up to 10 days. Results will then be compared to the operational model runs with the current SST analysis. For a seasonal forecast experiment at least 3 months of data would be necessary. However, it has to be stressed that the results of these experiments would rather indicate the impact of the new data set than its quality.

3.9 S. Pouliquen: CORIOLIS: A French Project To Collect And Qualify In-Situ Data For Operational Oceanography

The seven French agencies (CNES, CNRS, IFREMER, INSU, IPEV, IRD, METEO-FRANCE and SHOM) concerned by ocean research are developing together a strong capability in operational oceanography based on a triad including satellite altimetry (JASON), numerical modelling with assimilation (MERCATOR), and in situ data (CORIOLIS).

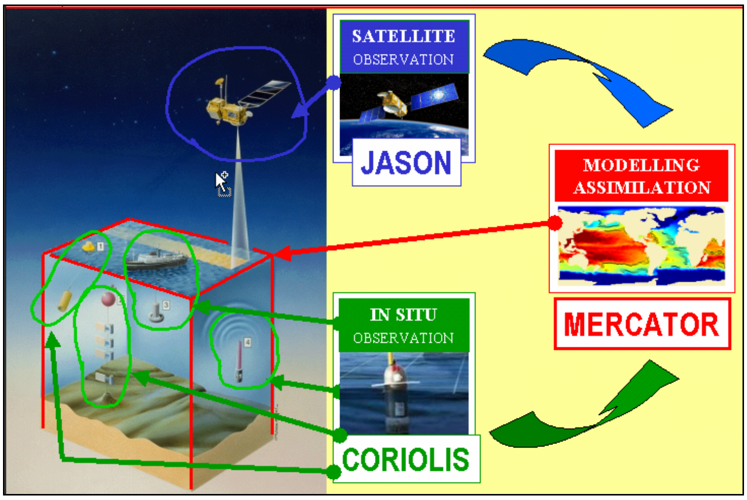


Figure 3.9.1 Schematic overview of the CORIOLIS project in relation to the JASON and MERCATOR projects. (S. Pouliquen).

The CORIOLIS project (shown schematically in Figure 3.9.1) aims to build a pre-operational structure to collect, valid and distribute ocean in-situ data to the scientific community and modellers. It's main goals are:

(1) To build up a data management centre, part of the ARGO network for the GODAE experiment, able to provide quality-controlled data in real time and delay modes.
(2) To contribute to ARGO floats deployment mainly in the Atlantic with about 250 floats during the 2001-2004 period.
(3) To develop and improve profiling ARGO floats.
(4) To integrate into CORIOLIS all other data presently collected at sea by French agencies from surface drifting buoys, PIRATA anchored buoys, oceanographic research vessels (XBT, thermosalinograph and ADCP transmitted on a daily basis).

Since 2001, the Coriolis data centre fulfils the operational oceanography data delivery requirements (48 hours from the observation to the Global Transmission System) and delivers daily data sets to modellers. The data are controlled with automatic procedures and checked by an operator if necessary. The total qualified data set is freely available through ftp and web interfaces. The CORIOLIS data centre process temperature and salinity measurements from Argo drifting floats, Thermosalinographs ,XBT&CTD data acquired on board oceanographic vessels. It also retrieve from GTS and qualify all available salinity and temperature measurements from XBT, ships, anchored and drifting buoys. Coriolis extends progressively its service to new data types:

- Moorings data from projects like Pirate;
- Thermosalinographs and full resolution XBT and CTD from scientific cruises;
- Integration of historical data sets to Coriolis data set (Woce Float data , NODC GTSPP XBT, historical scientific cruises when data are public….)
-

From 2001, more than 300.000 profiles have been collected and disseminated in real time by Coriolis data service with a world wide coverage. The historical data starting from 1990 represent more than 700 000 worldwide: http://www.coriolis.eu.org.

Coriolis data service also offers added value products such as temperature and salinity objective analyses maps (Atlantic ocean, see Figure 3.9.2)), maps of data distribution. It supplies statistics of data management activity and a permanent monitoring of the availability of the service.

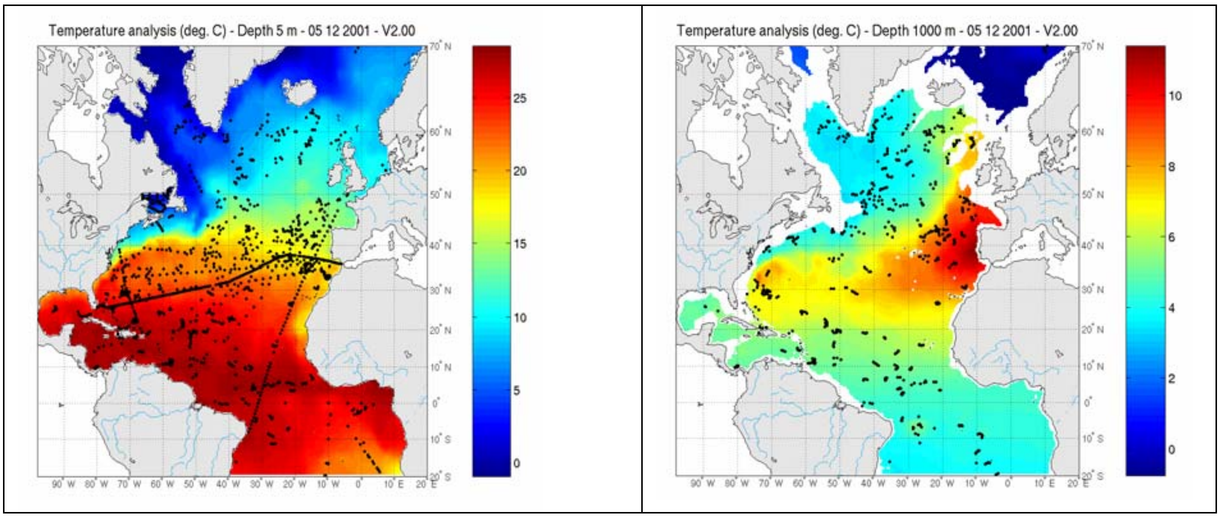


Figure 3.9.2 SST analysis and data distribution from the CORIOLIS data centre. (S. Pouliquen)

This in-situ database, daily updated by new datasets, can be an important contribution to the GHRSST in-situ Temperature data set the GHRSST-PP wants to build for the validation of the merged and analysed products he will generate. The expertise we acquired also in defining common data formats for CORIOLIS but also for the Argo program could also be used to speed up the standardisation process among the different contributors of this in-situ data base.

The CORIOIS data centre could provide the GHRSST-PP with a source of delayed mode (on the order of 1 week) quality controlled in situ SST data for use within the project. This is particularly relevant to the high resolution diagnostic data sets but also for the computation of validation statistics. Pouliquen suggested that the GHRSST-PP make a formal list of in situ data requirements and pass these to the CORIOLIS data centre.

3.10 A. Hines: Applications of GHRSST-PP products in FOAM

The Forecasting Ocean Assimilation Model (FOAM) is an operational ocean analysis and forecasting system developed and run at the Met Office. The operational models run daily, and are forced by 6-hourly surface fluxes from the Met Office's Numerical Weather Prediction (NWP) system. They assimilate in situ profile, surface temperature, sea-ice concentration and sea surface height data.

A coarse resolution global configuration of FOAM on a 1° grid with 20 vertical levels was implemented in the Met Office's operational suite in 1997. A configuration with 30 km grid spacing covering the Atlantic and Arctic oceans nested within the global model was implemented in 2001. These models run before 06Z each morning and produce 5-day forecasts, which are sent to Navy forecasters

The operational system is underpinned by a research system, which has recently focused on development of high resolution nested models. The capability has been developed to set up and spin up higher resolution nested configurations quickly for exercises. Major improvements have also recently been made to the data assimilation scheme. Firstly a technique has been developed for assimilating observations in a timely manner whilst taking proper account of observations which have already been assimilated. Secondly error co-variances have been calculated, using observational data, which represent the model errors as the sum of errors at the atmospheric "synoptic" scale and ocean "mesoscale" and the assimilation scheme extended to utilize them.

Real-time daily (and archived) pre-operational analyses from a 1/9° model of the North Atlantic are now freely available at http://nerc-essc.reading.ac.uk/las for research and development purposes (see Figure 3.10.1)

Hines concluded by summarising the characteristics of SST data required for the FOAM system noting that there were two distinct (but related) between the research and operational systems. For the research system:

- Model domains and resolutions are dynamic
    - global low resolution and regional high resolution SST data required
    - regional data requirements can change at short notice
- Data assimilation requires SST with
    - data error characteristics (required)
    - consistent in situ and satellite SST data
    - need data rather than an analysis
- For hindcasts and assessment runs several year long time series are required
-

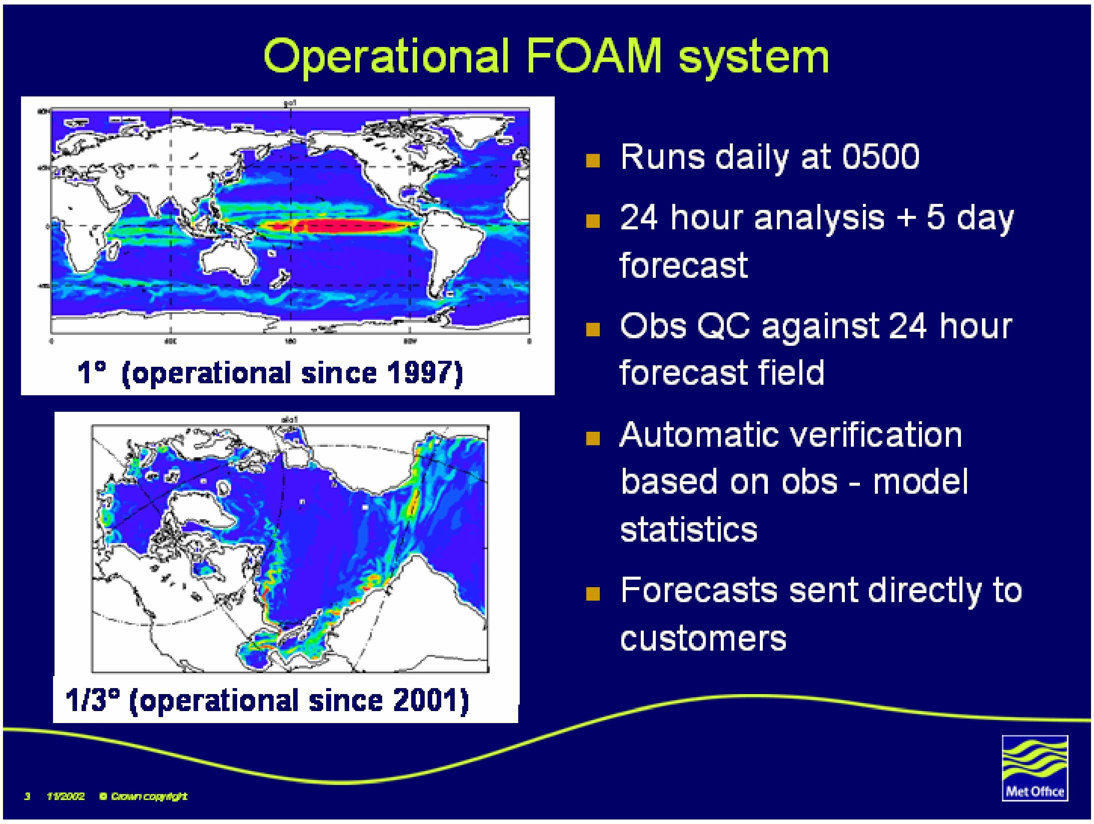


Figure 3.10.1 Details of the operational Forecasting Ocean Model (FOAM) at the Met Office, UK. (A. Hines).

For the operational system the following issues are of significant relevance:

- The **utility of supplied data**: demonstration of a positive impact on operational output is an essential precursor to operational implementation. But, this requires reasonable time series from operational data stream to assess
- **Timeliness and robustness** are critical issues
    - fast delivery data required as quickly as possible
    - operational systems will not wait for data to arrive
    - data stream needs to be reliable

- **Data must be controlled** with proper notification of all changes made in advance
- **Continuity:** the probability of continuity of the data stream beyond the demonstration phase must be very high
- **Format:** the format must be standard
    - WMO formats (e.g. BUFR, GRIB) best for operational Met centres
- **Delivery of data**
    - operational infrastructure inflexible
    - need flexible delivery methods and filenames
    - prefer data to be 'pushed'

3.11 E. Chassignet: Application of GHRSST-PP data products in GODAE.

Eric Chassignet began by reminding the workshop that the vision of GODAE is "A global system of observations, communications, modelling and assimilation, that will deliver regular, comprehensive information on the state of the oceans in a way that will promote and engender wide utility and availability of this resource for maximum benefit to society". The vision statement is founded on the relevance of GODAE in terms of

- Knowledge for societal benefit
    - The marine environment
    - Climate and climate change
- Predictive skill for societal, industrial, commercial benefit
- Tactical and strategic advantage
- Comprehensive and integrated approach to oceans

The requirements for High Resolution SST data products within GODAE differ for the following areas:

- High resolution operational oceanography requires accurate depiction of meso-scale features such as eddies and meandering fronts (global, scales of 10 km or less, daily, real time).
- Seasonal-to-inter-annual forecasts and climate applications require a good representation of the upper ocean mass field on scales from 25 to 50 km, globally, weekly to monthly.
- Coastal modelling applications will use GODAE high resolution model outputs for boundary conditions and will require finer resolution SST (order of 1 km, daily), but regional coverage.

Chassignet noted that SST products must be consistent in time and not influenced by changes that have occurred in the type and number of SST observations. This is especially true for SST analyses used for climate purposes since they span several years. In summary, GODAE requires the following from the GHRSST-PP data products:

- The vertical resolution in GODAE ocean models for the upper ocean is on the order of 5 to 10 meters leading to a preference for SSTdepth data for SST data assimilation
- The model skin temperature needs to be estimated from the model bulk temperature for heat flux calculations.
- Gridded data are preferred (even if these not available everywhere) with observational errors.
- The provision of estimated observational errors are essential for data assimilation. Errors should be computed appropriately.

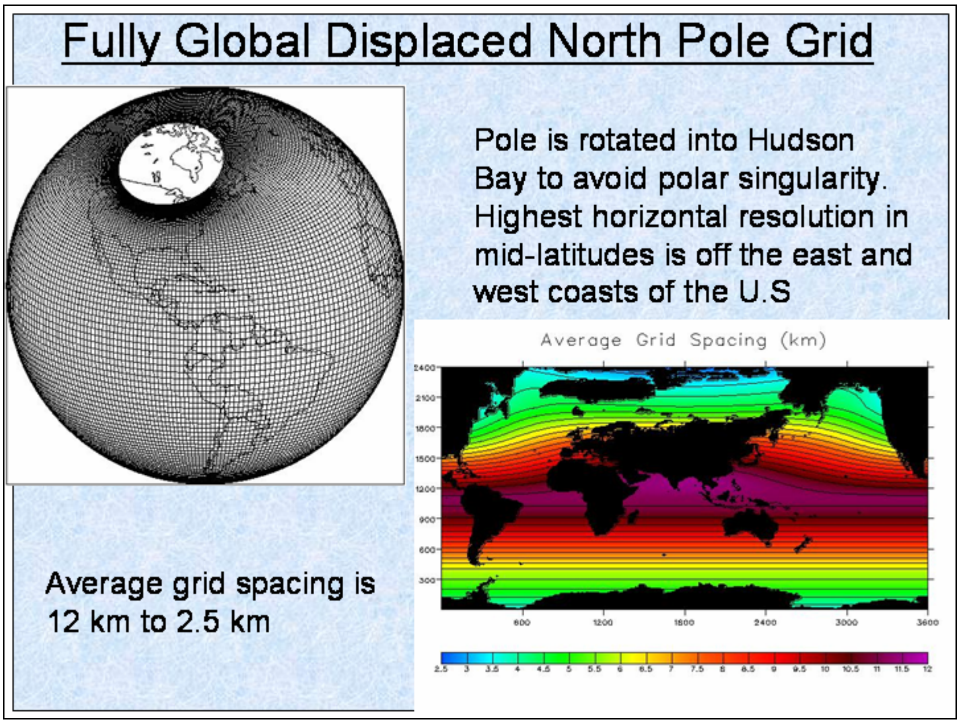


Figure 3.11.1 Example of a fully displaced north pole grid system. (E. Chassignet)

Finally, Chassignet noted that the GHRSST-PP should not be too preoccupied with the projection used for final output data products as most ocean models use a strange grid configuration (compared to a conventional projection, see Figure 3.11.1) and will re-project the GHRSST-PP data accordingly.

3.12 S. Eastwood: Operational use of regional high-resolution SST in a coupled ice-ocean model at Norwegian Meteorological Institute.

A high-latitude, near real time, sea surface temperature (SST) product with 10 km resolution has been developed at the Norwegian Meteorological Office (met.no) through the EUMETSAT project OSI-SAF (Ocean and Sea Ice Satellite Application Facility). The product covers the Atlantic Ocean north of 50°N and is produced twice daily. A digitized SST and sea ice map is produced manually once a week at the Ice Mapping Service at met.no using all available information from the previous week. This map is the basis for a daily SST analysis, in which the most recent OSI-SAF SST products are successively overlaid. The resulting SST analysis field is then used in a simple data assimilation scheme in a coupled ice-ocean model to perform daily 10 days forecasts of ocean and sea ice variables. Also, the associated OSI-SAF sea ice concentration product, is assimilated into the sea ice model.

Figure 3.12.1 shows the impact of the assimilation scheme used at met.no. In this Figure, (a) shows the analyzed SST (OSI SAF and Ice Mapping Service) as green lines and the model SST from a control run without any data assimilation as red lines for the analysis time (+00). Large differences of 1-2°C are visible between model and analyzed SST when the model is run without assimilation. In particular, the model is too cold the open deep waters and too warm in the more shallow North Sea.

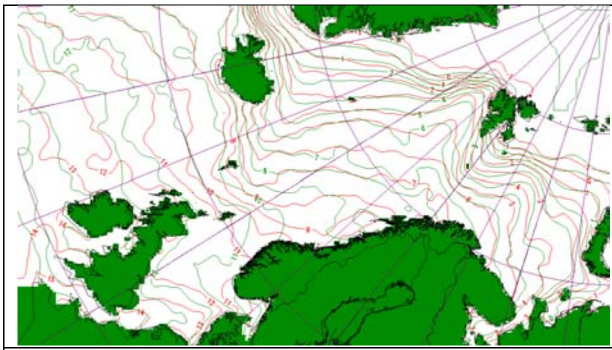
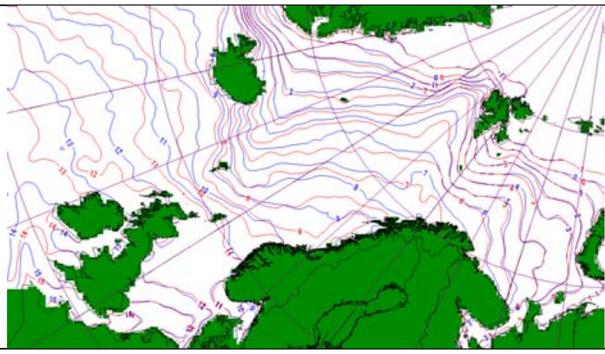
	
(a) Analyzed SST (green) and model SST from the main run (blue) at analysis time (+00)	(b) SST from the model run with SST assimilation (blue) and the model run without assimilation (red) at analysis time (+00)

Figure 3.12.1 Impact of the SST data assimilation scheme at met.no. (S. Eastwood).

In contrast Figure 3.12.1 (b) shows the SST chart from the model run with SST assimilation (blue lines) and the model run without assimilation (red lines) at model analysis time (+00). The warming effect of the assimilation is clearly seen and is a direct impact of the assimilation of SST data at the analysis time.

SST assimilation is presently only performed in a pre-operational ice-ocean model of the Nordic seas and Arctic Ocean on a coarse mesh (20 km) grid. Ongoing projects at met.no include development of SST assimilation schemes for use in shelf models on eddy-permitting fine mesh (4 km) grids. To accommodate the dynamical structures in the models, it is important that SST data are delivered on spatial scales no coarser than the model resolution (which in this case is smaller than the present GHRSST-PP data products of 10 km spatial resolution). The required temporal resolution of the data for assimilation has not yet been investigated.

Eastwood proposed the following SST product specifications for use at met.no:

- 2km resolution in seas around Norway.
- Both merged and analyzed products will be used, maybe reanalysed SST products.
- SSTskin, SSTsub-skin, SSTfnd
- Confidence Statistics and quality flags are useful.
- Product format: HDF and GRIB.

3.13 I. Barton: Fish and Farm Management in Australia Using SST

Ian Barton described three different applications of regional and local SST fields in Australian industries. Near-real-time (NRT) SST fields are used in a program which predicts fish catch for the Australian fishing industry. This avenue of approach is a successful way to convince the fishermen that satellite data can make their operations more efficient. SST fields are also used to predict water conditions in the coastal aquaculture industry. Recently some aquaculture stocks have been decimated through warm temperatures and the lack of rainfall. As these industries operate in regional areas, and the fish cages are transportable, accurate forecasts can be used to maintain fish stocks.

Barton noted that Sea-surface temperature (SST) is the dominant driving force on the atmosphere having impacts on the

- atmospheric moisture/humidity
- air temperature
- clouds → sunlight

- pressure patterns → wind speed and direction
- rainfall

Furthermore it has a long "memory" compared to the atmosphere

- seasonal to decadal compared to a few weeks
- high heat capacity (top 3m = entire atmosphere)
- slow speed of waves and currents

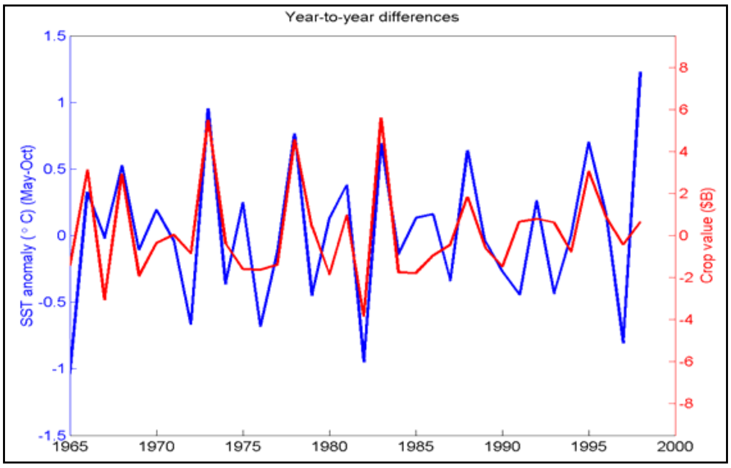


Figure 3.13.1. May-Oct SST anomaly for the period 1965-2000 plotted together with crop value in the Australian region (I. Barton).

Based on these simple observations it ought to be possible to have some predictive capability for land use/economic returns based on SST patterns. Figure 3.13.1 suggests that this is indeed the case.

There is some predictive skill using simple relationships based on SST patterns in the Australian region. The basic technique focuses on the calculation of a lagged statistical relationship between SST and variables such as plant growth based on historical data. Predictions can be made for future plant growth using present day SST measured from satellite. These must be tailored for region, industry and the desired decision point. Use partial least squares (PLS) to reduce the number of predictors to one or more spatial patterns. A typical example is shown in Figure 3.13.2.

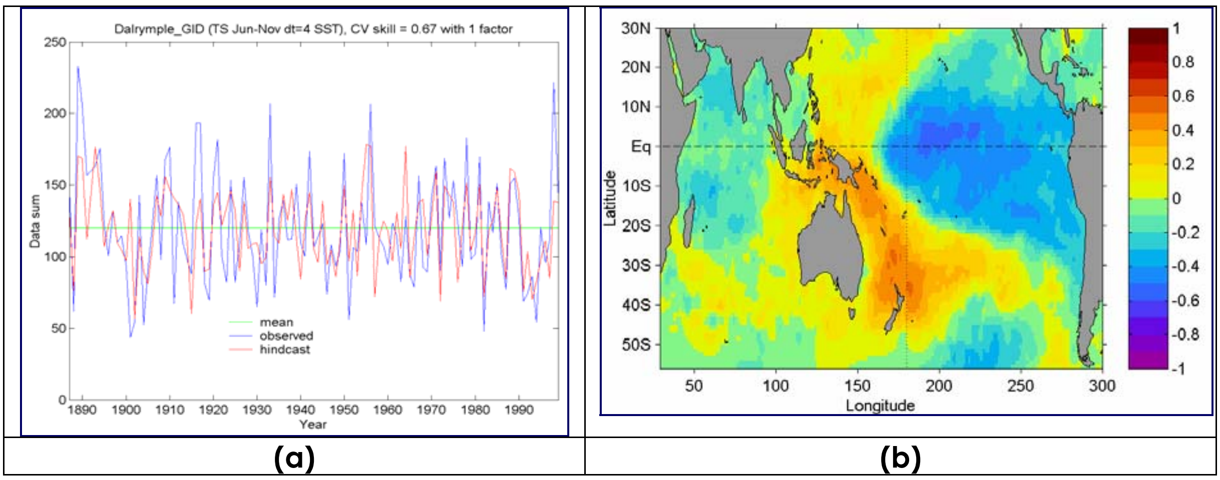


Figure 3.13.2. (a) Example of forecast and hindcast models for Dalrymple growth index based on SST patterns in the Australian region –shown in (b). (I. Barton).

The third application of SST fields is in the management of land-based farms on the Australian continent. An index based on SST distributions in the Indian and Pacific Oceans is a reliable predictor of farming conditions in the north-eastern state of Queensland. Stocking rates and woody weed control can be successfully managed using this SST-index. Indices in this "Oceans-to-Farms" project are under development for other Australian agricultural regions. Several relationships have been established based on specific but persistent SST patterns in the Australian region. These forecast techniques have allowed the derivation of an optimum strategy for the management of enterprise such as Tuna fishing and grazing enterprise.

4 Session 2: GHRSST-PP Internal component summaries December 3rd

This session was split into three separate sessions chaired by Hiroshi Kawamura, Chris Mutlow and Jorge Vasquez. It was designed to provide an forum at which developments towards implementing the major internal components of the GHRSST-PP could be presented and reviewed.

4.1 H. Kawamura: Towards the Japanese RDAC: The NGSST project and its second version.

The GODAE project has sent a "*Prospectus for a* GODAE SST Project" to the worlds SST researchers to encourage developments of high-resolution satellite-based sea surface temperature. Our group has been developed the new generation SST (NGSST), which is daily, high-spatial resolution, quality-controlled cloud-free SST products merging AVHRR, GMS and TRMM SSTs. Each of the satellite products are tuned against SSTs of the drifting buoys located in the Japanese region. Using the hourly GMS solar radiation and the surface winds from SeaWinds, SSMI and TRMM, diurnal effects are eliminated to adjust all SSTs acquired at different times in a day to the daily minimum SSTs at around 1m depth. Then, all SSTs are merged using an objective analysis for one year, October 1999 – September 2000. The diurnal variation is not treated explicitly, but implicitly involved in the product generation process.

Kawamura began with an overview of the ADEOS-II satellite system that provides an excellent platform for the investigation of SST through a combination of infrared and microwave SST. Kawamura noted that the Global Imager instrument will provide infrared SSTs at a high accuracy, fine spatial resolution with wide coverage that are very well complimented by the AMSR microwave SSTs having the capability for SST retrieval under clouds providing even better coverage. *In situ* SSTs are required to constrain these data sets as standard and reliable anchor points for the satellite SSTs.

Kawamura reminded the workshop that GODAE has a fundamental dependence of SST data and products. In particular, global perspective of GODAE demanded attention to the many gaps in present products (many not quantified) and improved representation of observational errors in data products. Cloud Mask issues for IR measurement and diurnal cycling of SST (Including the Bulk-Skin Problem) are issues for the GHRSST-PP internally. For GODAE the overriding demand is for increased spatial and temporal resolution set out in the GODAE prospectus for high resolution SST to be better than 10km and 24 hours.

Kawamura then explained the SST data requirements in the Japanese region which originate from the Meteorological Agency, Fishery Agency, Maritime Safety Agency (Coast Guard) and JAMSTEC. These are stated as:

- Daily One-degree Gridded Global SSTs for Weather Prediction (Real Time)
- Future Sea-Surface Boundary Layers Model for SST and Ice Predictions and Mixed-Layer analyses
- 10km Global SSTs for Fishery Use (Real Time)
- Daily Regional 1km SST for World Oceans (On-Demand but Real-time)
- Detection of all SST Fronts associated with significant oceanic currents (Real Time) 0.5K Accuracy and Continuous Supply

Particular attention was drawn to the fact that there are no Japanese user needs for diurnal SST information, although this remains one of the largest challenges for the GHRSST-PPP when combining different satellite data sets obtained at different times of the day.

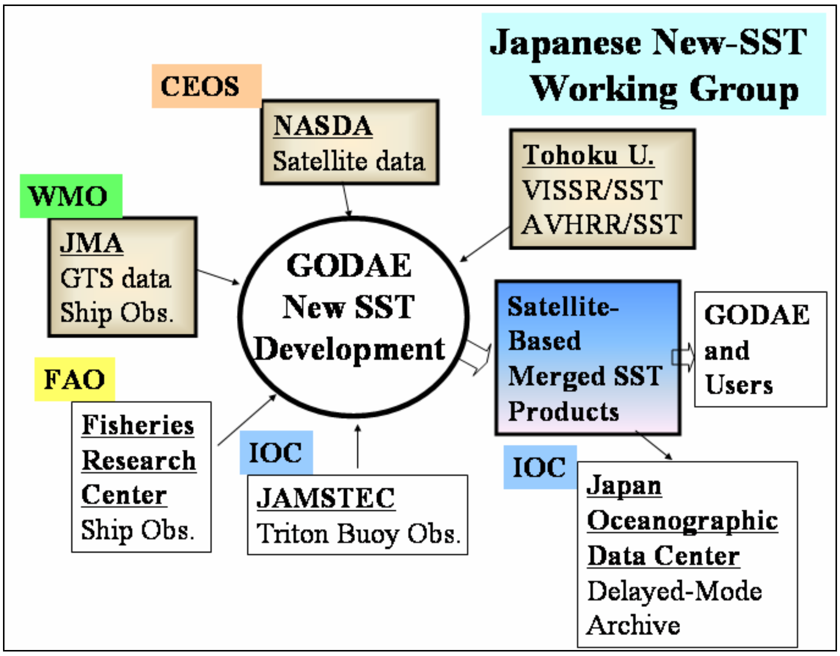


Figure 4.1.1 the Japanese new SST working group showing the importance of the Japanese RDAC effort.

The Japanese RDAC has concentrated on developing an SST1m data product to satisfy the needs of the Japanese SST data requests and to contribute GODAE. Part of the output is a demonstration of the method efficiency to the potential oceanographic user community. The first phase of the project runs over the time period 2000-2003 and the release of the first NGSST data product was achieved in July 2001. The second phase (NGSSTv2) of the project is focused on obtaining support from the user community in order to develop more advanced SST data products through a process of upgrade. For example, conducting physical & technological research on SSTdepth-SSTskin and diurnal effects variation. The second phase of the NGSST project will run between 2002-2005 and a first cruise aboard the "MIRAI" is scheduled for FY2003. A new SST working group has been set up in Japan for SST research which is shown in Figure 4.1.1

Kawamura reviewed the NGSST v1 data merging and data product production within the RDAC noting that the lack of time and space variant correlation length scales within the optimal interpolation scheme was a major limitation of the method. Furthermore, the NGSST-v1 has only been developed fro the Japanese area (GMS footprint). Collaboration with the Japan Meteorological Agency (JMA) has resulted in the production of a series of test data products that implement the NGSSTv1 methodology at a global resolution.

Kawamura then showed the results of an analysis of the NGSST-v1 data product using wavelet analysis. The aim of this work was to understand the temporal variability of the new products. Figure 4.1.2 shows the main results of this work.

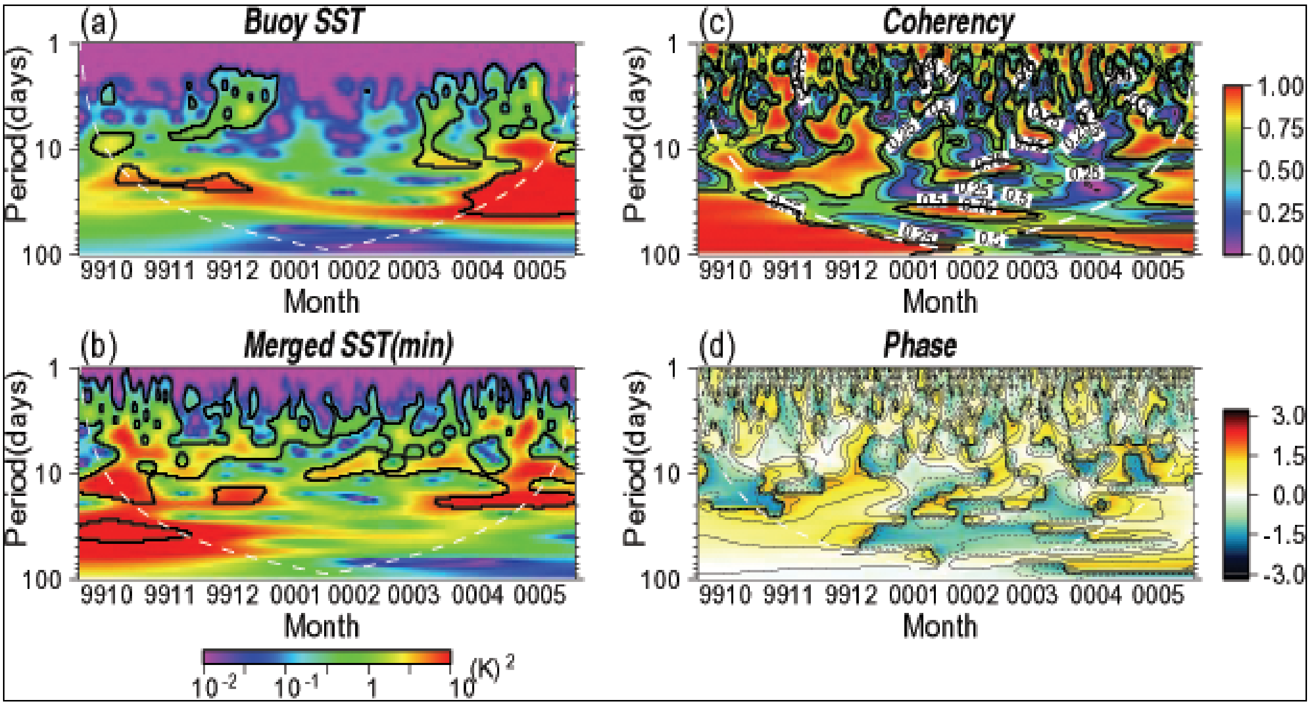


Figure 4.1.2 Results from wavelet analysis of NGSSTv1 data products (a) for in situ buoys, (b) for the NGSSTv1 merged SST, (c) coherency between (a) and (b), c() phase of (A) and (b) (H. Kawamura).

Figure 4.1.2 shows that the NGSSTv1 scheme has:

- Aliasing due to the TRMM/TMI sampling
- High coherence in autumn and low in winter to spring
- Serious cloud effect in winter due to lack of infrared SST
- Small scale oceanic features blurred through merging

The need for time and space dependent decorrelation length scales within the NGSST highlighted. The NGSST team have been working on this problem by computing 1- and 2D wave-number spectra for the NGSST area. This work highlights a significant seasonality of the wave-number spectra. In addition (as expected) there is a significant regional difference of the wave-number spectra. Based on these results, the NGSST team are now working towards a version 2 system that includes the following decorrelation scale with a spatial order of 2-3° and temporal order (2-3 day). These are strongly inhomogeneous, anisotropic and time-dependent (see Figure 4.1.3) when compared to the static scales used in the NGSSTv1 of 100km, 3day. The major forcing of these scales is thought to be atmospheric disturbance.

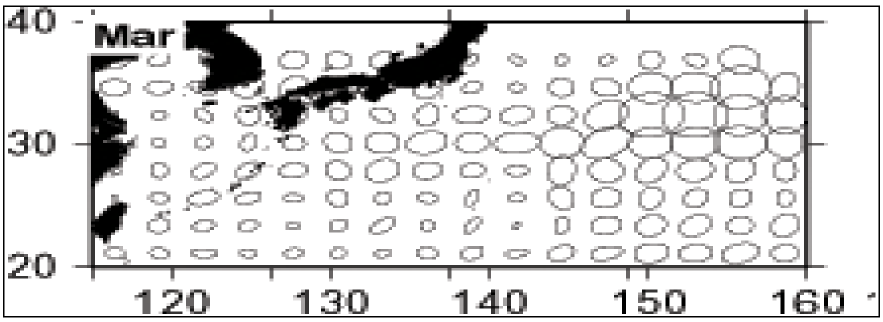


Figure 4.1.3 Decorrelation length scales used in the NGSSTv2 system for March 2002 in the Japanese area (H. Kawamura)

In addition, the NGSST method has been developed to include a new diurnal variation correction based on the use of a 1D physical model and a new merging procedure. Initial validation data show that the daily mean SST as an rmse=0.93, and daily minimum SST has rmse=1.03. Bias error is similar to the NGSST-v1 method.

Finally, Kawamura noted that the NGSST team had now begun to look at the combination of TRMM VIRS and TMI sensors which is work in progress.

4.2 G. Wick: A proposal to NASA for a USA RDAC

Gary Wick presented an overview of a proposal submitted to NASA called PEMSA: Production of an Enhanced Multi-channel SST Analysis which, if successful, would form the basis for a GHRSST-PP RDAC facility in the USA.. The main objectives of the proposal are:

1) Production of new, multi-sensor merged and analyzed SST products along with corresponding error estimates
2) Attainment of higher accuracy, resolution, and increased data coverage
3) Ensure the new products are responsive to the needs of and used by a broad user community and diverse applications
4) Rapid and enhanced electronic availability of the SST products to facilitate application
5) Provision of consistent, continuous products for the long-term SST record

PEMSA proposes three sets of data products broadly in line with the GHRSST-PP recommendations. These are:

Merged data products:
- SSTIR and SSTMW
- hourly fields at 0000, 0600, 1200, and 1800 UTC
    - No diurnal compensation (average of measurements or unique selection)
- 9.28 km spatial resolution (1/12 degree)

Analysed data products:
- SSTskin and SST1m
- Daily minimum values
- Added Diurnal information
    - Amplitude
    - Time of peak warming

Reanalysed data products: Based on the above but taking advantage of non-real time data streams

Figure 4.2.1 shows the general data processing flow proposed for the PEMSA project which links the US GODAE server as a large scale data archive system to the PO.DAAC acting as a deep storage data archive and user interface. PEMSA proposes that data processing is performed using a dedicated cluster data processing computational facility (DPCF) supercomputer.

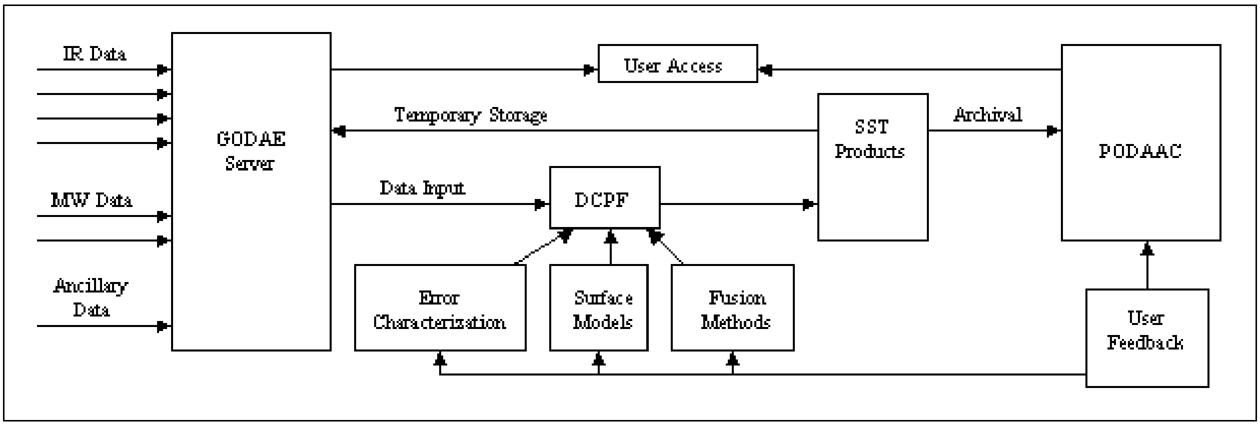


Figure 4.2.1 General data processing flow proposed for the PEMSA project (G. Wick).

The DPCF was specified according to Table 4.2.1 based on some of the discussions at the 2nd GHRSST-PP workshop in Tokyo. The DPCF will be used to implement an optimal interpolation system (e.g. Reynolds and Smith, 1994) to generate analyzed SST data products. In addition, a limited amount of diagnostic and R&D can be performed using the system in parallel with the analysis operations providing a means to build an operational system while at the same time develop and test new methods using the same operational data streams used by the operational code. Also, new methods can be easily incorporated into the operational code as these will have been tested using identical code but in a parallel run.

The PEMSA project will depend on the use of in situ validation data from the recent National Ocean Partnership Program (NOPP) BAA calling for a demonstration of widespread ship of opportunity radiometer deployments in support of satellite validation experiments. In addition, it will make use of both moored and drifting buoys.

Number of nodes	16
Number of processors per node	2 Intel Xeon @ 2 GHz
Memory per node	2 GB
Disk storage per node	40 GB IDE
Network (GigaBit)	1 per node
Rack mounting	
1 U Rack mounting for expandibility	
Red Hat Linux	
Portland Group FORTRAN and C compilers	
IDL Software	
Maintenance contracts	
FNMOC support	

Table 4.2.1 Specification of a Data Product Computational Facility for the PEMSA project. (G. Wick)

4.3 O. Arino, Ian Robinson & P. LeBorgne Towards a European RDAC: The Medspiration project

Olivier Arino began by noting that the European Along Track Scanning Radiometer series (ATSR/1, ATSR/2) now provides an unprecedented archive of global coverage SST data for the investigation of climate dynamics spanning over 10 years. This is now being extended further using the Advanced ATSR carried aboard the ENVISAT platform. The European Space Agency (ESA) will contribute to the GHRSST-PP by making the AATSR data archive available to the project through the standard ESA Category-1 project process. In addition, ESA will also promote the development, implementation and operation of a European system for integrated SST in specific areas with the view of sustainability e.g., Mediterranean/N Atlantic areas. The basis for this approach is the GHRSST-PP Global/Regional task sharing approach to the provision of operational SST data products. In this sense ESA will be providing an EU RDAC centre. The regional projects will implement the RDAC and feed the GHRSST-PPGDAC providing:

- Regional data merging and analysis
- Regional error statistic generation
- Regional DDS data extraction
- Regional product validation
- Regional user application feedback

The mechanism for realizing this commitment is through the ESA Data User Element (DUE) Process that is dedicated to supporting earth observation application user communities (including both science and industry). The project will be called Medspiration and will contain the elements described in Figure 4.3.1.

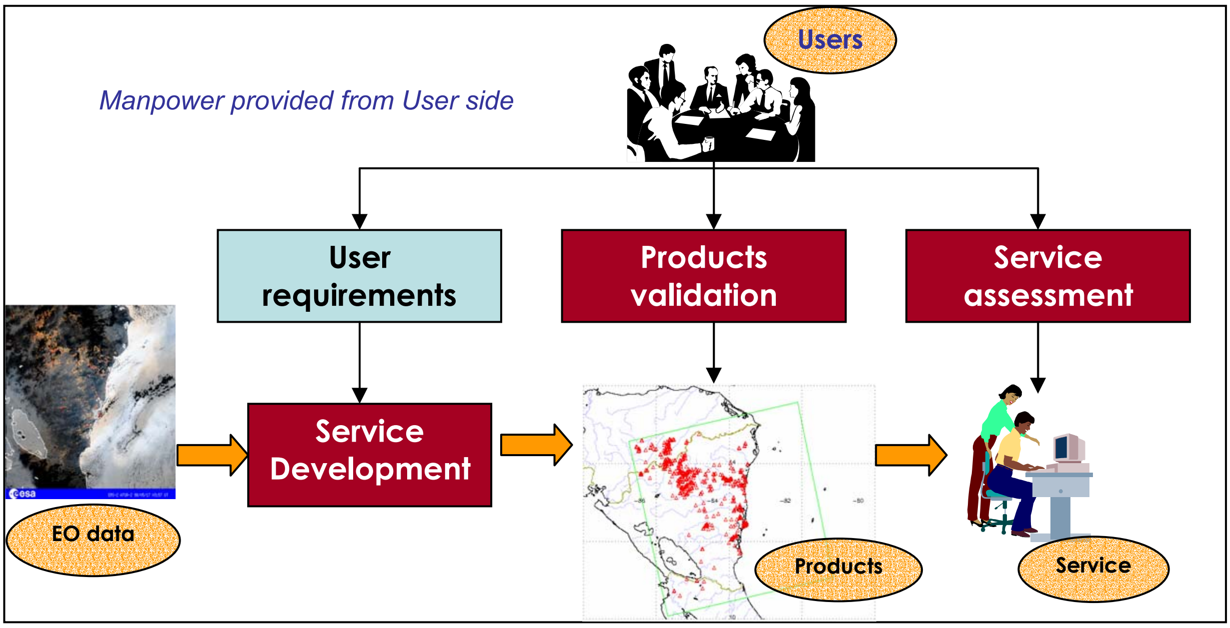


Figure 4.3.1 Essential elements of the Medspiration DUE project (O. Arino)

In order for the Medspiration project to pass appropriate DUE benchmarks the GHRSST-PP must demonstrate a considerable User Commitment by providing the following documents:

- *User Requirement*
- *A Detailed Processing Model*

- *Conduct Validation/collect in situ data during the project*
- *Undertake an assessment at end of project*

It is expected that an ITT will be announced in early 2003 for the Medspiration project with an aim to start the project in July 2003.

Ian Robinson then suggested that the main aim of Medspiration should be to develop, implement and demonstrate a system for providing:

> *"A European capability to produce a new generation of multi-sensor, high resolution (better than 10 km), sea surface temperature (SST) products to be provided in real time (6 hourly) to meet the anticipated needs of European regional operational ocean forecasting systems"*

Practically, Medspiration will enable European scientists to make a significant contribution to the implementation of the International GHRSST-PP during 2003 -2005. Figure 4.3.2 provides a schematic overview of the main elements for the proposed Medspiration data processing scheme based on the requirements of the GHRSST-PP identifying the key data processing steps and satellite sensors.

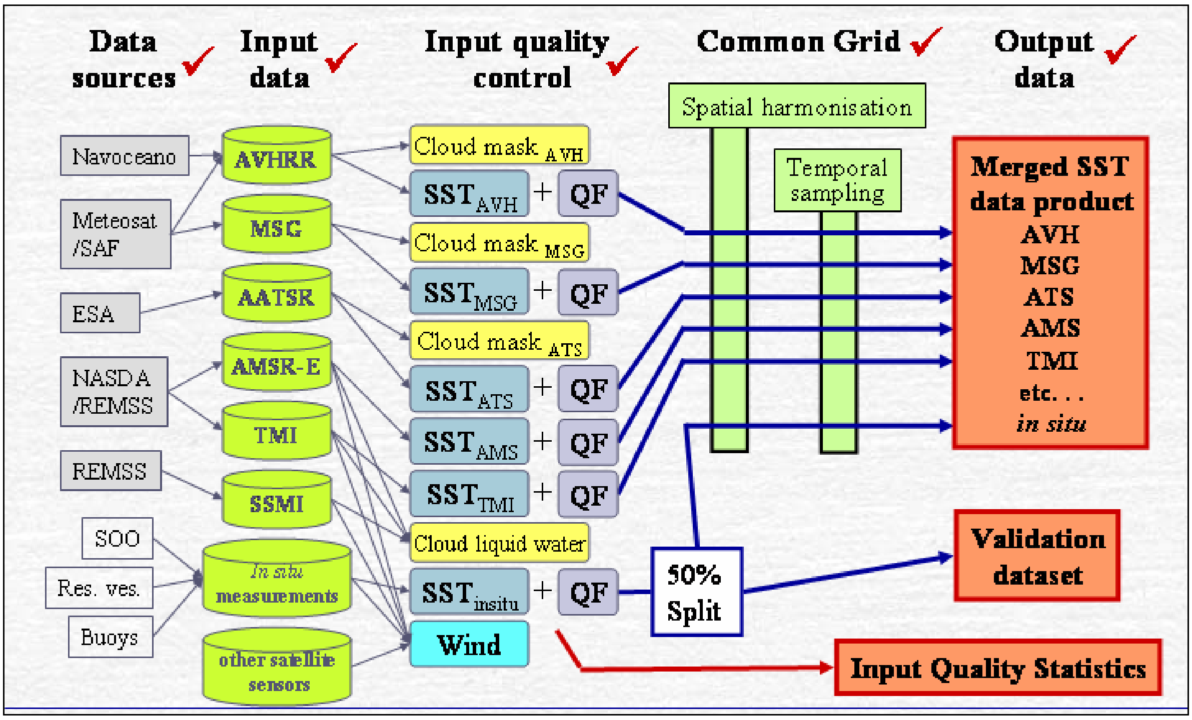


Figure 4.3.2. suggested elements of a data processing specification for the Medspiration project.

Robinson concluded with an assessment of the importance of the Medspiration project for the GHRSST-PP and European users of SST data products which is summarised in Figure 4.3.3.

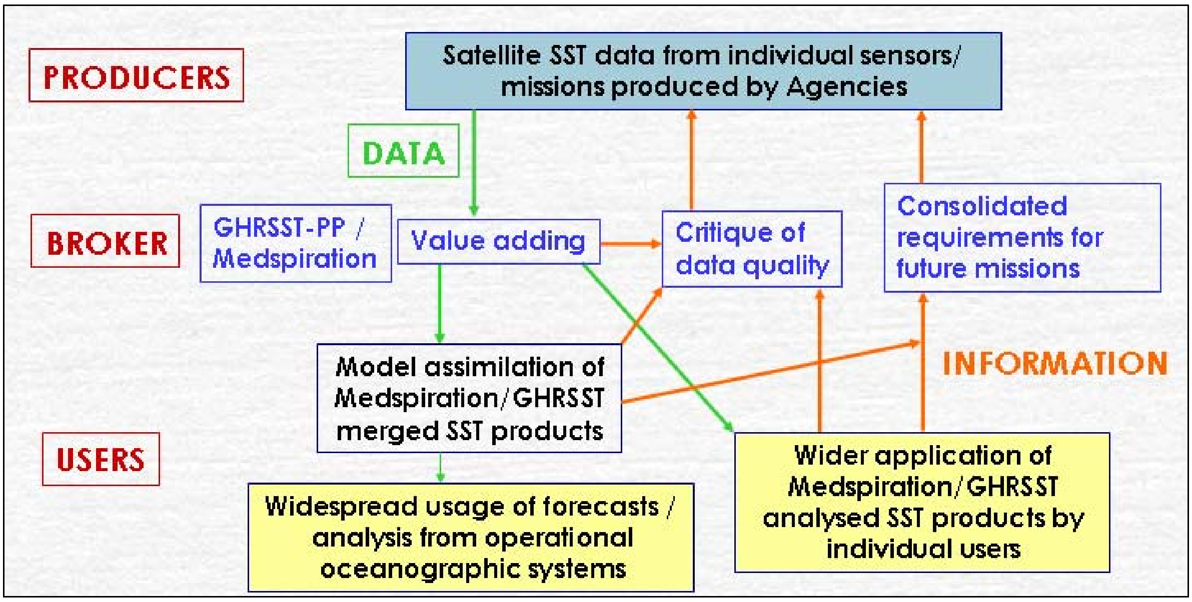


Figure 4.3.3 A view of the role of the GHRSST-PP RDAC/Medspiration project

Medspiration may be viewed as a 'broker' of SST connecting SST users with SST data producers. The project is value adding through the application of SST data within European data assimilation systems and the derivation of GHRSST-PP data products which leads to more widespread use of forecasts. In addition, through a critique of data quality, Medspiration feeds back information to data providers providing a mechanism for developing consolidated requirements for future satellite missions. Ultimately, Medspiration will lead to a better use of satellite and in situ SST data sets and the wider application of data products within GHRSST-PP and the wider operational and scientific community. Arino concluded that the timescale for the Medspiration project was:

- ITT: March 2003
- Kick Off: July 2003
- Prototype SST products: July 2004
- Full validated service: July 2005

4.4 N. Rayner: GHRSST-PP and Climate data sets

Effective monitoring systems for climate should adhere to the following GCOS Climate Monitoring principles*:

- The impact of new systems or changes to existing systems should be assessed prior to implementation.
- A suitable period of overlap for new and old observing systems is required.
- The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.
- The quality and homogeneity of data should be regularly assessed as a part of routine operations.
- Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
- Operation of historically-uninterrupted stations and observing systems should be maintained.

- High priority for additional observations should be focussed on data-poor regions, poorly-observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
- Long-term requirements should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
- The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.
- Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Furthermore, satellite systems for monitoring climate should adhere to the following specific principles:

- Rigorous station-keeping should be maintained to minimize orbital drift.
- Overlapping observations should be ensured for a period sufficient to determine inter-satellite biases.
- Satellites should be replaced within their projected operational lifetime (rather than on failure) to ensure continuity (or in-orbit replacements should be maintained).
- Rigorous pre-launch instrument characterization and calibration should be ensured.
- Adequate on-board calibration and means to monitor instrument characteristics in space should be ensured.
- Development and operational production of priority climate products should be ensured.
- Systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.
- Continuing use of still-functioning baseline instruments on otherwise de-commissioned satellites should be considered.
- The need for complementary in-situ baseline observations for satellite measurements should be appropriately recognized.
- Network performance monitoring systems to identify both random errors and time-dependent biases in satellite observations should be established.

For GHRSST-PP to be useful in the context of climate monitoring, all of the above should be satisfied. In addition, Requirements of 0.1K/decade stability for climate change detection purposes are now thought to be incorrect. Climate change signals have already been detected using the surface network (see IPCC reports). Rayner explained that the challenge now is to develop data sets for model verification and climate monitoring, which require long term stability and a small observational error in any calculated trend (although studies of processes may have less stringent requirements). Considering an error at 10% of the expected signal, then such an error can be ignored. If the error is 25%, it must be explicitly included in calculations. If it is 50% then it is a major problem. Considering an expected climate signal of global warming at 0.2K/decade, ideally SST stability of 0.02K/decade is required. This is a stringent requirement and will demand exceptional quality control of all input data sets if it is to be met. The GHRSST-PP reanalysis group should consider this specification as a serious target.

Finally Rayner suggested that the likely use of GHRSST-PP data products at the Hadley Centre (assuming the data are of sufficient quality) would be:

- To aid in understanding of the climate SST record: uncertainties, sub-grid variability

- Use of diurnal warming estimates in AGCM experiments
- Verification of high resolution ocean modelling
- Could incorporate into parallel version of HadISST

4.5 K. Casey: The GHRSST-PP Re-Analysis Project (UIS-RAN)

Since its inception, the GODAE High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP) has acknowledged the need for a delayed-mode reanalysis suite of products that makes best use of a variety of data and techniques that may not be available in real-time production. The report of the First GHRSST-PP Workshop identified two key features of a reanalysis suite:

(1) consistency with existing SST climate datasets and
(2) higher accuracy when compared to real-time products.

It also pointed out that such products are often utilized in unexpected ways by previously unknown user groups. This concept is an extremely important one, and any reanalysis strategy should consider that the data would be used in many unforeseen ways by both current and future generations.

The proceedings of the Second GHRSST-PP Workshop expanded on these initial features, illustrating, for example, the push by climate researchers for a standard SST measurement (such as 1-meter SST) and that the GHRSST-PP reanalysis products should contain this standard parameter. It also highlights that a reanalysis scheme must properly account for the GHRSST-PP real-time use of varying input datasets and the impact such a system can have on a climate record. The Second Workshop also identified the need for the inclusion of accurate sea ice and ice edge information in a reanalysis suite and the importance of consistent treatment of input data sets to the extent possible. Furthermore, it highlighted the requirement for proper documentation of data and algorithm changes and the mandate for a capability to completely reprocess the GHRSST-PP data streams when changes in data or methods warrant it.

Following the Second Workshop, several possible characteristics of reanalysis SST products were identified. These characteristics include a global resolution of 10 km or better with selected areas of 2 km resolution, twice-daily temporal coverage, absolute accuracies of less than 0.3 K, and delivery timescales on the order of weeks to months. These specifications taken along with the recommendations from the First and Second Workshops serve as the starting point for discussions of the GHRSST-PP Reanalysis Plan. Details of this plan must consider issues such as the proper spatial resolution, necessary temporal sampling, and minimum delay time to insure adequate improvements in the accuracy of the reanalysis products. Other issues include careful identification of ancillary data and techniques that may result in delayed-mode improvements to the reanalysis products. For example, will better-modelled winds and heat fluxes be available in delayed mode that can be used to better resolve the diurnal signal in a reanalysis product?

A GHRSST-PP reanalysis team has been convened to guide the development of the GHRSST-PP reanalysis project. This team has been working informally for several months chaired by Ken Casey. The justification for a reanalysis project within the GHRSST-PP itself is founded on the realisation that real-time operational products, with their focus on the present and future, often fail to deliver a consistent time series suitable for climate and related applications. Several reanalysis projects provide several key lessons for the GHRSST-PP:

- Provide ancillary data
- Carefully document even the smallest changes in algorithms or processing
- Provide adequate user support
- Create realistic data release schedules
- Carefully analyze budget requirements
- Consider impact of algorithm decisions on "error recovery"
- Remember that these data will be used in many previously unimagined ways!
- Remember that these data are likely to be reprocessed again (and again…)
- Actively develop a user community

Casey noted that the GHRSST-PP reanalysis plan should support a standardized SSTdepth product for climate applications, account for varying input data sets, include sea ice information, provide excellent documentation and enable a reprocessing capability. In addition, it should resolve SST twice-daily at 10 km or better at an absolute accuracy of < 0.3 K and be delivered within a timescale of weeks to months.

In terms of realizing these goals, the GHRSST-PP reanalysis project must be able to provide delayed mode products of higher accuracy and consistency than real-time merged or analyzed products. This means applying techniques and data not available to real-time analyzed products and, more importantly, applying changes made to the real-time data products retrospectively to the *entire time series - and perhaps to even earlier data*. In addition there must be a link between this suite of products and longer-term SST analyses. This can be established by accounting for biases between the various datasets, promoting overlapping records, in situ bulk, and in situ radiometer data will be especially useful in this effort. In this context, the GHRSST-PP Diagnostic Data Sets (DDS) are critical. The GHRSST-PP reanalysis project should also insure proper stewardship of data such that future users may easily reprocess or utilize the data. In practice this means providing an efficient archive and access capabilities to the original data streams, developing standards based metadata, documenting carefully all analysis methods and changes and maintaining vitality of the data through active research and application.

Casey concluded with a request for input from all Science Team members to the GHRSST-PP draft reanalysis implementation plan.

4.6 S. Hankin and F. Blanc: The GODAE Data Sharing Pilot Project (presented by C. Donlon)

On June 12, 2002 the GODAE Data and Product Server Workshop was held in Biarritz, France (http://www.bom.gov.au/GODAE/Projects/ServerWS/). The goals of the workshop included "to develop a strategy for adoption of agreed data and serving standards, including approaches for developing a broader-based community standard." A consensus emerged from that Workshop to begin a GODAE Data Sharing Pilot Project based upon the OPeNDAP data transfer protocol and the Live Access Server (LAS) for browsing and inter-comparison of data on the Web. This document describes the project's background, its goals, and the software components and data standards that must be implemented to participate in the DS Pilot.

4.6.1 Background

The Global Ocean Data Assimilation Experiment (GODAE) is an effort to enhance the effectiveness of operational ocean modelling and state estimation activities through international cooperation. Through shared access to the pipeline of data from participating GODAE sites, including observations, products, and forecasts, and attendant modelling and data management techniques, such as quality control, data assimilation, and model physics, the community can more rapidly advance the state of ocean modelling and achieve a useful, operational, global ocean modelling capability.

GODAE is a loose collaboration of volunteer organizations. There is no central organization with a mandate or funding to support the collaboration, nor with the authority to impose uniform data standards. Thus, a data sharing strategy which can succeed must permit the participants to operate with great independence. The participating GODAE sites will be peer-to-peer in the sense that each participant is both a data provider (server) and a data user (client) – each using the availability of data from other sites to evaluate and improve its own products. Sites may install and remove their own data sets asynchronously. The data sharing system must minimize the barriers to participation in terms of effort, complexity, costs (hardware and software), and the imposition of data standards that may be incompatible with on-going operations at each site. Its challenge will be to achieve a scientific consistency, ease of use and reliability that approaches what one might expect from a carefully curated data collection, where in reality the data sources are distributed, asynchronously modified and heterogeneous with respect to grids, resolutions, and formats.

Each participating organization has made investments over many years in the development of research tools for visualization and analysis of data. These investments represent far more than the costs of software licenses; the ability to work with familiar tools is a key consideration in the productivity of a research group. To the degree possible, the GODAE Data Sharing System must enable participants to continue using their familiar tools. The System should deliver the shared, distributed data sources interactively to those tools. To facilitate collaborative discussions the system should also provide a suite of standardized visualization tools and model metrics, and it should apply these tools when comparing models to models, models to data products, and models to observations. These capabilities should be available through standard WWW browsers and should be designed to support collaborative discussions.

4.6.2 Scope of the Pilot

The GODAE Data Sharing Pilot is a voluntary effort on the part of the GODAE participants to deploy and test components of the Data Sharing System described in the preceding section. The Pilot effort took shape at the Data Management workshop that was held in conjunction with the "En Route to GODAE" Symposium in Biarritz, France, 13-15 June, 2002 (http://www.cta-congres.com/BIARRITZ2002/twogoda.html). Participation in the Pilot is open. The DS Pilot will limit itself initially to a subset of the functionality that is envisioned in the mature DS System. Specifically, the pilot will focus initially only upon the inter-comparison of model results. Through a sequence of milestones the Pilot will advance from its initial capabilities to a mature distributed model-data inter-comparison system. Section 4. Milestones addresses the phases of the DS Pilot.

The Pilot will be built upon two existing data management components which together appear to meet the GODAE DS needs – OPeNDAP (a.k.a. DODS) and the Live Access Server (LAS). Table 4.6.1 enumerates the types of functionality that should be available in the mature system -- "*" marks those aspects of the functionality that will be **excluded** from the initial pilot.

On the server (data providers) Data types included in pilot

- gridded model outputs
- gridded data products
- (*) real-time *in-situ* observations

Data sets may be added/removed asynchronously at each site
Grid types supported

- rectilinear (irregular coordinate spacing on axes)
- curvilinear
    1. note: differencing operations between curvilinear grids will not be supported in the initial Pilot. Configuring curvilinear grids in LAS will require manual effort initially.

<u>On the desktop</u> (tools that will be capable of accessing shared data sets)

- Matlab
- IDL
- Ferret
- GrADS
- ncdump
- (*) ncbrowse
- (*) Excel

<u>Access via standard Web browsers</u> (NetScape 4,6,7 or IE 4,5,6)

- all contributed data sets (from distributed locations) will appear through a single Web interface
- user may select custom space-time region and variable from any data set
- on-the-fly graphics
    - lat-long maps
    - vertical sections
    - vertical profiles
    - time series
    - Hofmuller (evolution) plots (like mooring lines)
    - user-specified contour levels, palettes
    - (*) in-situ: property-property, scatter plots, “waterfall” plots
    - (*) sections along arbitrary tracks in lat-long (e.g. ship tracks)
    - (*) custom visualizations configured by data providers
- subsetting capabilities
    - arbitrary 4D “rectangular” subsets
    - multi-variable downloads
    - output formats
        - COARDS netCDF
        - tab-delimited
        - ASCII (FORTRAN readable)
        - quick look ASCII table
        - (*) CF netCDF (for curvilinear grids)
- comparison capabilities (comparing distributed model runs)
    - differences (with automated regridding)
        - (*) Note: not available for curvilinear grids in the initial Pilot. Group discussions of regridding techniques will be necessary to fully implement differencing

capabilities
- graphical overlays
- side-by-side plots
- standard comparison diagnostics
  - (*) to be determined

Table 4.6.1: Capabilities of the GODAE Data Sharing Pilot "*" indicates exclusion from the initial stages of the pilot

4.6.3 Overview of LAS and OPeNDAP (a.k.a. DODS)

The Data Sharing Pilot will be built upon a foundation of two existing data handling systems: the Open Project for a Network Data Access Protocol (OPeNDAP, formerly known as DODS) and the Live Access Server (LAS). Both are available free of license costs and are actively supported: OPeNDAP at http://unidata.ucar.edu/packages/dods/ and LAS at http://ferret.wrc.noaa.gov/Ferret/LAS/ . For both systems the underlying philosophy is similar: data should be managed independently at participating sites. When a user make a request of LAS or OPeNDAP -- to see a data visualization, to extract a subset of data, or to compare variables from two different sites – the systems hide the differences in data management techniques between sites. Individual sites may independently choose file-naming conventions, how long to keep files on line, whether variables are stored in individual files or consolidated, etc.. (Note, however, that a higher degree of standardization in data management in the initial stages of the DS Pilot will greatly reduce the complexities of setting it up.)

4.6.4 OPeNDAP

OPeNDAP is middleware that provides uniform binary-level access to scientific data on the Internet. There are three components to OPeNDAP: servers, client libraries, and a format-neutral data transport protocol. The protocol may be thought of as XML-tagged data descriptions (metadata) with associated non-parsed (binary data) content. (*Note: OPeNDAP predates XML. As of 9/2002 a conversion to XML encoding is in progress. No significant changes in functionality are expected through this conversion.*)

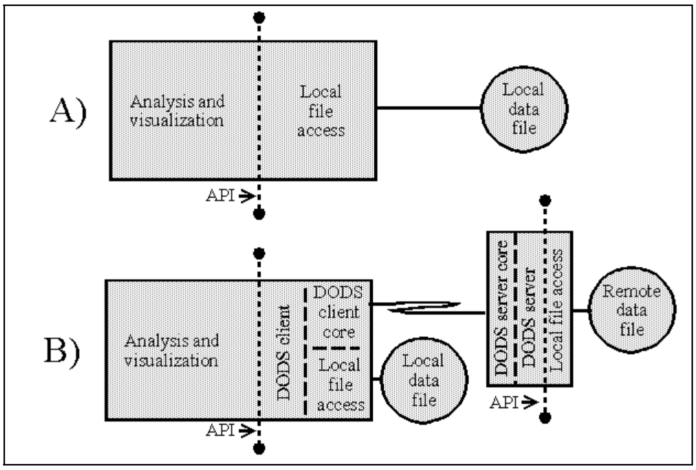


Figure 4.6.1. Adding OPeNDAP capabilities to an existing application Cartoon A) illustrates the Application Programmer Interface (API) as the boundary across which a scientific application makes requests to its local file access libraries (e.g., netCDF) to read and write data files. Cartoon B) illustrates the same scientific application re-linked with OPeNDAP. The OPeNDAP client mimics the API used for local file access, directing the requests to the local file access libraries, or to the network as appropriate.

Within the data protocol the so-called "syntactic metadata", which describes the structure of the data (Grids, Sequences, Structures, etc.) is mandatory, however, most semantic information is optional. OPeNDAP servers provide access to existing formatted files (netCDF, HDF, ASCII, …) through the OPeNDAP protocol. Servers are typically available as binary executables that the data provider can quickly install. Existing and new client applications are supported through the OPeNDAP client libraries. Support for clients that utilize netCDF is particularly simple, as the netCDF native libraries have been OPeNDAP-enabled so that a simple relinking of an application is often sufficient to OPeNDAP-enable it (see figure 4.6.1).

OPeNDAP has been designed to minimize the barriers to sharing data over the Internet. Thus a data provider will often be able to begin serving data through OPeNDAP within a matter of hours. (See the OPeNDAP Web site at http://unidata.ucar.edu/packages/dods/ to see the list of quickly supported server types.) Data users will often find that their familiar scientific applications can directly access OPeNDAP data. The list of supported applications includes IDL, Matlab, Ferret, GrADS, excel, and others. The OPeNDAP protocol has also been designed to be very general and discipline-neutral. Thus the protocol has not required significant alteration since its inception in the mid-1990s and it serves a broad range of data, including oceanographic, atmospheric, and even astronomical data. In optimizing for ease of entry and generality OPeNDAP accepts a trade-off not to guarantee that rich, detailed semantic content will be included in the protocol. To obtain this guarantee OPeNDAP requires that other standards be layered upon it. For the GODAE Pilot Data Sharing project the "CF" standard will provide the higher level semantics -- see http://www.cgd.ucar.edu/cms/eaton/cf-metadata/.

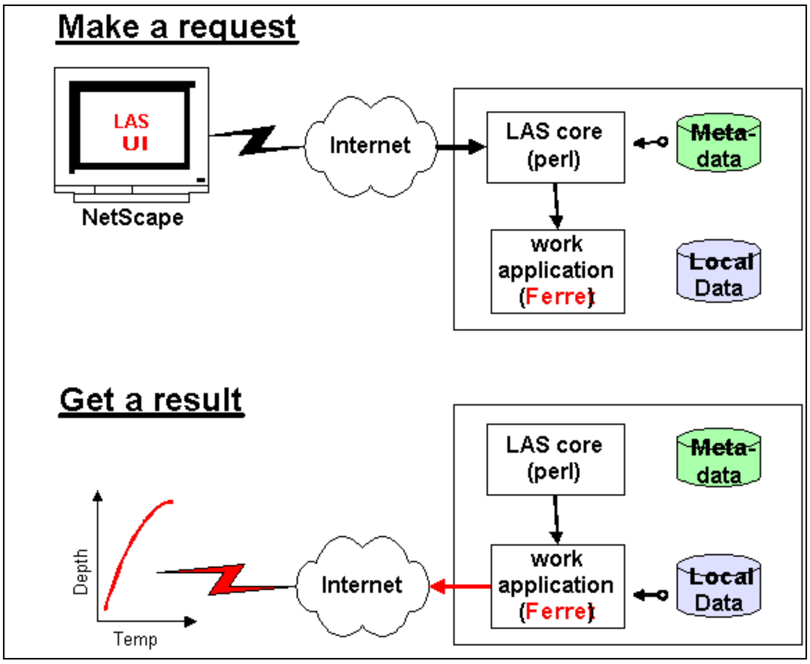


Figure 4.6.2. the Live Access Server (LAS) is a "product server"

4.6.5 The Live Access Server (LAS)

LAS is a configurable scientific data "product" server (see figure 4.6.2). It provides a friendly user interface to ocean/atmosphere/climate data browsing, download, and comparison on the Web. A user can quickly obtain products such plots, images, and formatted files generated on-the-fly from custom subsets of variables. Comparison mode allows the user to difference (with automated regridding) variables, overlay them graphically and view them as side-by-side plots.

LAS may be configured to provide specialized products such as the model comparison metrics that will be required for GODAE. XML configuration files may be edited by the installer of LAS to add and remove products (a.k.a. "operations".) LAS does not create products, itself, rather it redirects the users' requests for product creation to one or more "back end" applications. LAS coaches the back end applications as to what resources to use (scripts to run, color palettes to use, etc.) and where to find the data (path names or URLs).

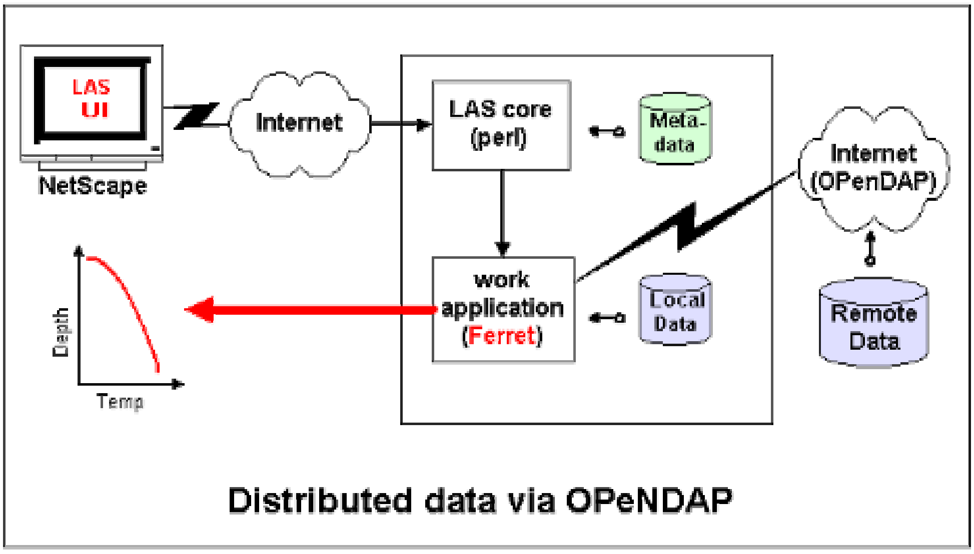


Figure 4.6.3. Remote data access with OPeNDAP (formerly "DODS")

LAS comes pre-configured to use Ferret as a back end application. Ferret is free, scriptable, and handles visualization, sub-setting, differencing, and mathematically transforming of most classes of ocean and atmospheric data. If a participating GODAE site prefers to use other software tools to create products (graphics, animations, GIS layers, etc.) these may be incorporated as back end operations into LAS[1]. If the back end application supports OPeNDAP access to remote data (as Ferret does) then LAS becomes a distributed data server (see figure 4.6.3). *Note that for the initial stage of the Data Sharing Pilot we will require all participants to utilize the default LAS back-end, Ferret, in order to ensure that the distributed data access simple and uniform.*

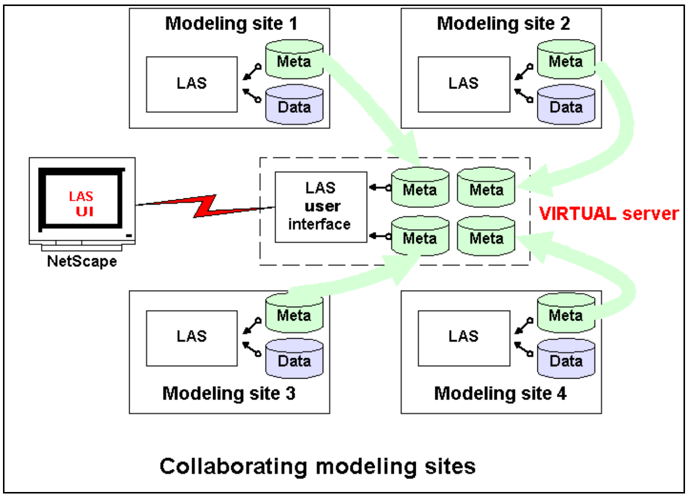


Figure 4.6.4. LAS "sister servers"

[1] LAS back-end applications must be able to run from a command line and if producing graphics must be able to do so without the need of a physical display. More details are provided in the LAS Installation Guide

The "intelligence" of an LAS site lies entirely in its XML configuration files (and associated back-end resources.) These files define not only the operations that are possible, but also the data sets, variables, units, space-time domains, etc. -- in short, the information necessary to present a user-interface to the data. By making copies of their XML configuration files and associated resources available for a consolidated (virtual) site a group of LAS sites can be configured as a collaborating "sister server" cluster (see figure 4.6.4). At the consolidated (virtual) site a single user interface provides access to the collective holdings. The consolidated user interface may reside on a separate computer or on any of the sisters. The virtual site directs the requests for products to the sisters that host the relevant data. Only comparison operations must occur on the virtual user interface server, itself, which then must utilize OPeNDAP to access the distributed data at the binary level.

4.6.6 Architecture of the GODAE Data Sharing Pilot

The GODAE Data Sharing Pilot will implement the architecture described in the preceding sections. Each participant will host an LAS site that provides Web access to the data the participant provides. The sharing of XML configuration files from all participating sites will be accomplished by a cron job, which runs on the consolidated (virtual) server, periodically picking up the latest configuration files from the sisters and regenerating the virtual user interface. It is when synchronization occurs that the consolidated user interface server becomes “aware” of changes to the data holdings of the participating sisters. In the GODAE Data Sharing Pilot we will initially create the consolidated (virtual) site at PMEL, as described in the preceding section. As soon as it becomes stable one or more mirror sites will be established in Europe. We anticipate initially that automated synchronization will occur once every 24 hours. Synchronization may also be triggered on demand by the manager of the consolidated user interface site. This is useful if a sister site requires more frequent synchronization during periods of testing.

The ability to make comparisons between data sets and to compute metrics based upon them is vital to the Data Sharing Pilot, as well. This level of collaboration requires the user interface server to access distributed data at the binary level, rather than simply requesting products from distributed servers. As of October 2002 there is significant additional effort difficult to configure LAS sisters to perform comparison. In order to minimize these difficulties the Data Sharing Pilot will initially require the uniform use of Ferret as the LAS back end. LAS version 6.3, planned for July 2003, will relax this requirement.

4.6.7 Technical Requirements for Participation

Table 4.6.2 lists the technical requirements to participate in the GODAE Data Sharing Pilot project.

Table 4.6.2: technical requirements to participate in the GODAE Data Sharing Pilot project.

System requirements – see LAS V6 installation instructions for details
    Linux/Pentium or Solaris *1
    HTTP server (Apache 1.3.x recommended)
    Perl 5.6.0+
    mySQL
    Java 1.4
    Disk resources:
        Data to be shared must be on-line
        LAS -- approx. 100 Mbytes
    Tomcat Java servlet engine
 	
Outside access (security)

LAS URL to be accessible to other GODAE data providers (full public accessibility preferable)
LAS LivePack (XML configuration) output for sister server connections t.b.d.

Software to be installed and configured
a. OPeNDAP server version 3.2 or higher
b. LAS version 6.0 or higher
2.1 Ferret V5.4+ (discussed in LAS installation)
c. (optional) OPeNDAP Aggregegation Server

Data to be shared
a. Gridded data, only (initial pilot)
a.1 **Data formatted as CF** (or COARDS)-compatible netCDF files *2
a.1.1 See http://www.cgd.ucar.edu/cms/eaton/cf-metadata/ for CF specifications and XXX for user guidelines on structuring netCDF files that are as easy to use as possible)
b. Must be installed on spinning disk accessible to LAS and the OPeNDAP server
c. LAS configuration information must be updated as per LAS documentation *3
c.1 See section 2 for a discussion of when synchronization occurs
.

Notes:
1. LAS is not supported on other operating systems. Source code is available for those without axis to Linux/Solaris and users have successfully hosted LAS V5 on Compaq Unix and Irix.
2. Any OPeNDAP accessible format may in principle be utilized -- including HDF, flat binary or ASCII, or SQL data bases. The more restrictive requirement of CF-adherence is to simplify the deployment of the initial stages of the Data Sharing Pilot.
3. A single conceptual data set often consists of an aggregation of multiple files, with a sequence of files containing the time history. Model forecast outputs are typically of this type. Four methods of aggregation are suggested -- all are adequate:
i. OPeNDAP Aggregation Server (available at http://www.unidata.ucar.edu/projects/THREDDS/tech/AggServerStatus.html)
ii. GDS (GrADS/DODS Server) (available at http://www.iges.org/grads/gds)
iii. append a sequence of netCDF files into a single data set via nco ("netCDF operators" – see http://nco.sourceforge.net/). This method is limited by the maximum size of a netCDF file -- approximately 2 gigabytes. (This limit is expected to be raised in the next version of netCDF from Unidata.)
iv. Ferret descriptor file (see http://ferret.wrc.noaa.gov/Ferret/Documentation/Users_Guide/current/fer_html.html -- Ch10 Sec4. CREATING A MULTI-FILE NETCDF DATA SET) Note that this approach will provide aggregation only for LAS and Ferret as a desktop application, only -- it will not provide remote aggregation services to other OPeNDAP-enabled clients such as IDL or Matlab. The descriptor file should be built of OPeNDAP URLs, rather than of local file paths.

4.7 E. Armstrong and J. Vasquez: The GHRSST-PP Master Metadata Repository (MDR)

The large volumes and diversity of satellite, in situ and ancillary oceanographic data for the GHRSST-PP require careful accounting in the form of searchable metadata records. This is important from the standpoint of end users who wish to query metadata records from a number of different GHRSST DDSs (Diagnostic Data Sets) for certain products in specific temporal and spatial regions.

We propose the design of a "master" metadata repository (MMR) that is indexed and searchable through a web interface front end communicating with a back end database server. The simplest approach is use open-source database software such as mySQL that is straightforward to install and maintain. The database contents will be accessed through Perl and SQL function calls with results formatted in XML that can be displayed in a web browser. The query results can also be formatted into DODS or FTP syntax to allow immediate and direct access to the DDS where the data resides (a location different than the metadata repository). The goal is to keep the metadata storage and query on a very simple level while maintaining good functionality with possibility for future modification and expansion.

An automated metadata ingest system will be constructed (see Figure 4.7.1) to ingest metadata submissions as new data are added to the various DDSs (both high resolution, regional and global). This ingest system will be in the simple form of email submissions emanating from the DDS that are parsed with scripts to extract relevant metadata content before the database is populated.

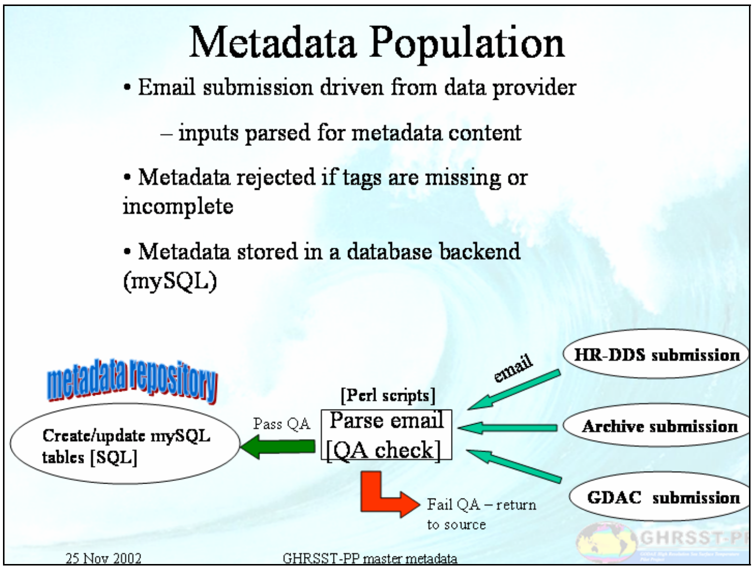


Figure 4.7.1 Proposed automatic system for the GHRSST-PP Master Metadata Repository system. (E. Armstrong).

A quality control system will be implemented to determine if the metadata adheres to the proper format (NASA Directory Interchange Format [DIF]). The submitting individual will be responsible for formatting the metadata input correctly according to the required fields and metadata templates. Metadata creation tools and methodology will be explored to assist the submission process.

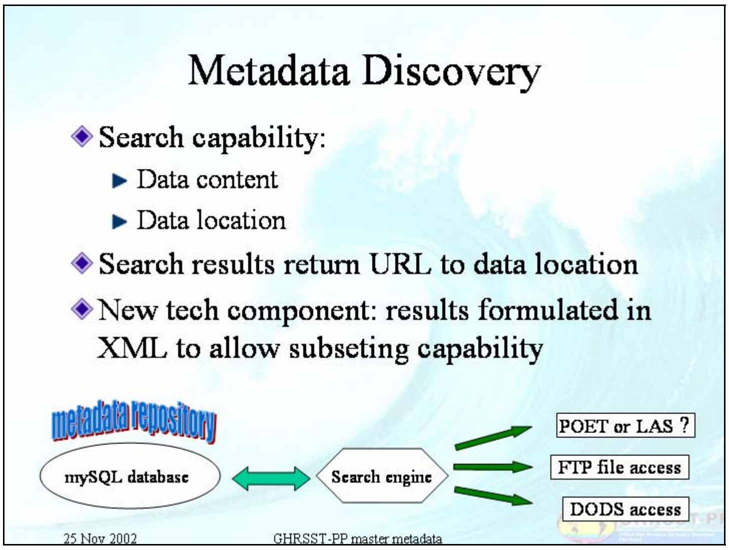


Figure 4.7.2 MMR system for GHRSST-PP, data discovery (E. Armstrong)

In order to make use of the MMR, a data discovery system must be designed that allows a user to search for data by several fields addressing the data content (at a minimum by time and location). The search should then return a URL to the location of the data within the GHRSST-PP distributed data set (see Figure 4.7.2). It is proposed that XML is used for reporting results so that sub-setting of results can be undertaken.

4.8 J. Vasquez and E. Armstrong: Towards the GHRSST-PP User Information Services Data Active Archive Center (UIS-DAAC) and Data Product Server (UIS-DP)-The PODAAC Experience

The Physical Oceanography Distributed Active Archive Center (PODAAC) has been, for several years, serving the oceanography community through the distribution of satellite derived sea surface temperature (SST) data sets, along with ancillary data sets such as the AVHRR Pathfinder match-up database produced by the University of Miami. The experience of SST distribution through the PODAAC can prove useful within the framework of setting up both the UIS-DAAC and the UIS-DP.

Primary contact between the user community and PODAAC distribution process takes place through the PODAAC User Services Office (USO). The PODAAC is structured such that a given data set responsibility falls onto individual data set engineer. Questions about specific data sets coming to the PODAAC are then answered by USO members or if highly technical passed onto the data set engineers themselves. The combination of USO and expertise of the engineers, with their data set of interest, has proven very successful in dealing with the user customer base of the PODAAC. 'Tasks' at the PODAAC describe the core activities that the USO uses to "do whatever it takes" to provide users with the best possible products and services. The common tasks include:

- Customer Support
    - Handling users requests and correspondence
    - Referrals
    - Documenting interactions
    - Listening, anticipating trends
    - Resolving issues
- Statistics
- PO.DAAC Public Policy
    - Web, brochures, bulletins, etc
- Conference Participation
- Product Roll-out Advertising & Marketing
- Outreach/Informal Education
- Documentation Review
- Product/Tool Testing
- Liaison
- DAAC Alliance/USWG support
- Policy Development
- Feedback Analysis
- Internal Processes

Tasks are relatively fluid in that particular tasks are stable for up to a year at a time but large (and often positive) changes occur every year or so.

Several tools are used at the PO.DAAC that have been developed over the years by PO.DAAC software engineers to help track data orders & inquiries. In particular CAHOOTS (formerly DOTS) provides a tool for Data Order and Tracking together with a Customer

Support Log. In addition, a USO Notebook (see http://seanet.jpl.nasa.gov/uso/notebook) provides a log of all communication with users. Together, these tools and the engineers at the PO.DAAC provide a powerful customer support system that ensures the PO.DAAC provides the best possible support to customers. This type of system is required by the GHRSST-PP User Information Services (UIS) component and Vasquez proposed that the PO./DAAC should play a major role in this part of the GHRSST-PP. The PO.DAAC can also provide support to the applications and User Services component of GHRSST-PP although the operational nature and requirements of individual agencies using high volumes of GHRSST-PP data will require careful thought on a case-by-case basis.

The PO.DAAC has four main access channels for users (possibly identical for GHRSST-PP?):

1. **Email** (podaac@podaac.jpl.nasa.gov, or jpl@eos.nasa.gov)
2. **Web page** (http://podaac.jpl.nasa.gov)
3. **Phone** (626-744-5504)
4. **EOS Data Gateway (EDG)** (http://podaac.jpl.nasa.gov/~imswww/pub/imswelcome/)

User web orders generated by the web page (podaac/order) sometimes bypass the USO and get dumped into CAHOOTS directly, where they're handled by Operations (OPS). These typically include

- Educational products (3 CDs, poster, doc package)
- Some data CD-ROMs (GOSTAplus, WOCE, AOS)

The majority of orders are directed to the USO's email box (all tape orders and some data CD orders) for review. If the USO deems the order legitimate, typically one of the following actions is initiated:

- All CD-ROM, CD-R & educational orders get forwarded to OPS for data entry and filling
- Most tape orders get entered into CAHOOTS by USO (except for distribution products)

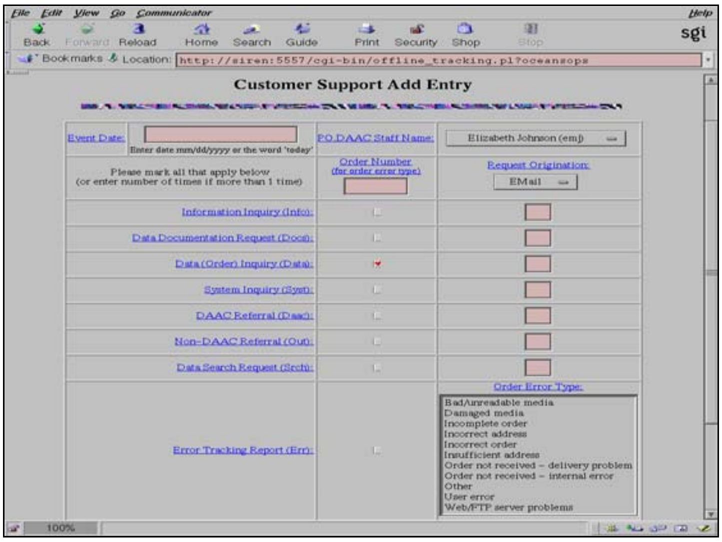


Figure 4.8.1 USO notebook entries data entry interface. (J. Vasquez)

Most data orders get logged into USO Notebook (except for straightforward, off-the-shelf product requests where no further user interaction is expected) as shown in Figure 4.8.1. If the order is not legitimate or questionable (for any number of reasons), USO staff will first query the User. In some cases it the help of a Data Engineer may be required. All interactions are logged as an 'interaction' in the Customer Support Log (CSL) & Notebook.

In addition to data orders, the USO provide support to user inquiries. When an inquiry is received, the question is evaluated and the team provide an answer based on their knowledge. An interaction with a Data Engineer is often initiated as part of the inquiry-response process to address some issues. All interactions are again, logged.

Month	AVHRR/MCSST			N/QSCAT			JASON		
	Users	Hosts	Comb.	Users	Hosts	Comb.	Users	Hosts	Comb.
01/2002	95	281	313	105	255	283	6	8	9
02/2002	118	260	302	93	243	271	4	6	7
03/2002	89	272	295	80	283	301	4	15	15
04/2002	115	361	400	105	292	318	15	43	47
05/2002	109	306	344	96	240	269	17	44	48
06/2002	89	374	399	81	232	251	9	26	27
07/2002	119	309	335	97	211	243	13	34	41
08/2002	100	357	386	86	207	233	2	23	23
09/2002	107	444	490	104	252	285	2	29	29
10/2002	148	450	519	138	284	345	3	32	32
* 11/2002	90	248	272	61	142	152	2	16	16
2002	662	2946	3384	506	1915	2282	37	115	138

Figure 4.8.2 Typical statistical report of data orders/access using the USO facilities at the PO.DAAC. (J. Vasquez)

The USO infrastructure allows for the collecting of statistics on the distribution of the data through the different interfaces the PODAAC supports (see figure 4.8.1). These interfaces include FTP access, web interface, sub-setting through different tools such as (PODAAC Ocean ESIP tool), POET, and the data ocean distribution system (DODS). Sub-setting tools have been implemented for several of the SST data sets, including pathfinder, Reynolds, and the MCSST data. These tools work in various fashions, with sub-setted data sets accessible directly through the web, or via anonymous FTP.

Vasquez proposed that the GHRSST-PP UIS_DAAC could be implemented through the PODAAC framework and uses the current PODAAC structure for user contact, statistics, and sub-setting capabilities within the UIS-DP framework. Experience has shown, that for high resolution global data sets, sub-setting capabilities are crucial for easy and efficient access of the data.

4.9 J. Vasquez: The GHRSST-PP Diagnostic Data Set

Several requirements for the GHRSST-PP HR-DDS (High Resolution Diagnostic Data Set) have been formulated by the GHRSST-PP science working team. In order to fulfill these requirements the DDS needs to encompass a wide range of geographical regions that are readily accessible by the user at real-time to near real time rates. It also needs to include validation data sets that consist not only of in-situ buoy and radiometer data, but also additional remote sensing data sets, such as heat-flux, wind speed, and aerosols. Thus the DDS must also be accessible by a wide range of users at a real time rate, with data providers having maximum flexibility in distribution and format. The Distributed Oceanographic Data System (DODS) provides one solution for such a data set, allowing the data to be appropriately distributed by the data provider. Vasquez presented several examples of data sets distributed through DODS at the Physical Oceanography Distributed Active Archive Center (PODAAC). These include the current AVHRR Pathfinder 9km SST data set, as well as the 4km MODIS Level 3 data. Vasquez noted that since the implementation of the DODS system at the PODAAC, it has had 80000 hits.

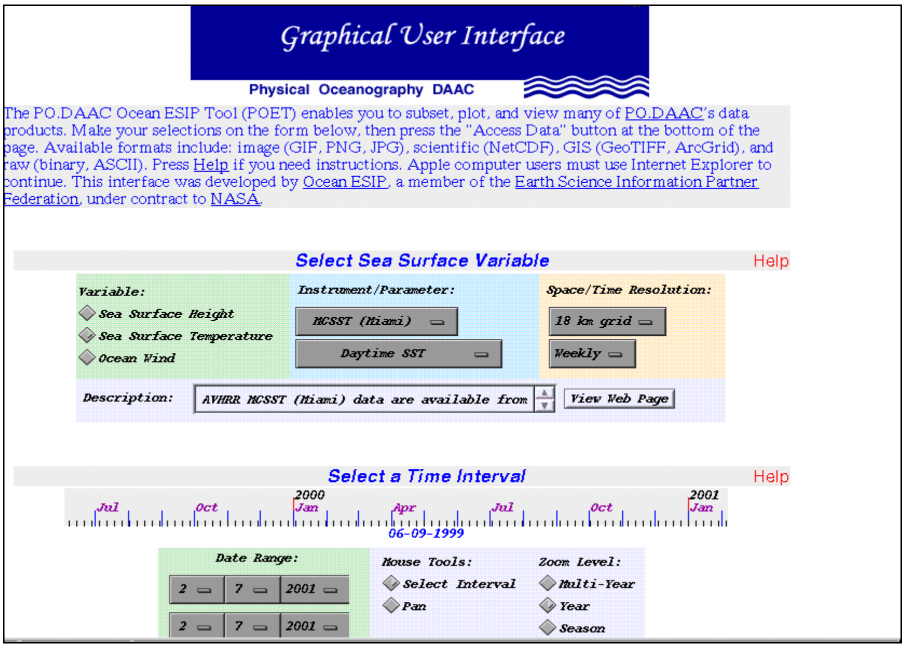


Figure 4.9.1 The PO.DAAC POET web interface. (J. Vasquez)

Vasquez then provided an overview of new tools that are being developed at the PO.DAAC that are well suited to the requirements of the HR-DDS. The main tool is an interactive web-based system called POET that provides the functionality of a DODS system but includes a dedicated graphical front end (see Figure 4.9.1). The system is still in development but provides a fast intuitive interface including area selection by mouse, coordinate entries by hand and data selection. Tools such as POET provide sub-setting for HR-DDS (and LAS) which are critical for users accessing HR Data in regional areas.

Vasquez then discussed the Pathfinder SST match-up database developed by the University of Miami and served at the PO.DAAC. This provides an excellent example of an in situ validation data set provided with a satellite derived SST data set. Vasquez noted that the GHRSST-PP goal should be to provide similar data set (ideally building onto the Pathfinder data set or at least having a high level of compatibility), in the framework of the DDS, through the DODS system. The goal can be achieved by combining a metadata database, such as the Global Change Master Directory (GCMD), within the DODS system. This will allow for both the search capability and extraction of the appropriate data set by the user. Ideally distribution of HR-DDS data should be done by the data provider with archiving and metadata storage at one location. Such a model could be based on the current GCMD and DODS protocol, with archiving being done at such locations as the PODAAC or another data center. Finally, Vasquez noted that metadata indexing the HR-DDS should form part of the GHRSST-PP master metadata repository (MMR) system.

4.10 C. Donlon, S. Pinnock, and Ed Armstrong: Implementation of the GHRSST-PP high resolution Diagnostic Data Set (HR-DDS)

Donlon began by explaining the purpose of the HR-DDS which is to develop a manageable data resource and framework for sharing of data to enable pixel data inter-comparison and analysis of SST and other related satellite and in situ data at daily or even hourly resolution. The primary outputs expected from the HR-DDS include:

- Quality control and monitoring of input satellite data streams
- For understanding differences between complementary data
- Evaluating and developing SST bias correction strategies
- To develop, test and, validate ISDI data-fusion tools, strategies and methods
- Generation of error/confidence statistics for input and output data streams and GHRSST-PP data products
- The validation of GHRSST-PP data products.

A basic draft implementation plan for the GHRSST-PP the HR-DDS is in place on the GHRSST-PP web site (GHRSST/14). This was a technical document meant to provide a uniform description of the HR-DDS metadata and file structures as well as a reference document to those groups contributing to the system.

The HR-DDS is a means to provide the GHRSST-PP with a "Scientific Virtual Laboratory" that cross-cuts all operational and scientific project components. It is the GHRSST-PP quality control tool both within the operational and scientific components of the project and for the output data products via validation experiments. The implementation plan proposed the HR-DDS as a distributed database system based on OPeNDAP (DODS) technology with data holdings linked via local metadata repositories linked to the GHRSST-PP metadata repository (MDR). Data are shared and accessed by DODS/OPeNDAP/sftp and web based services (e.g. POET).

The current location of HR-DDS sites consists of ~150 HR-DDS 2x2° areas and the data holdings for each area should include all available (but relevant) data for the HR-DDS site updated and used in near real-time as far as practically feasible. In this sense, regional RDAC projects would be the natural provider of HR-DDS for their area. Figure 4.10.1 shows the location of HR-DDS sites following feedback and discussions at the 2nd GHRSST-PP workshop (Tokyo, Japan, May 2002).

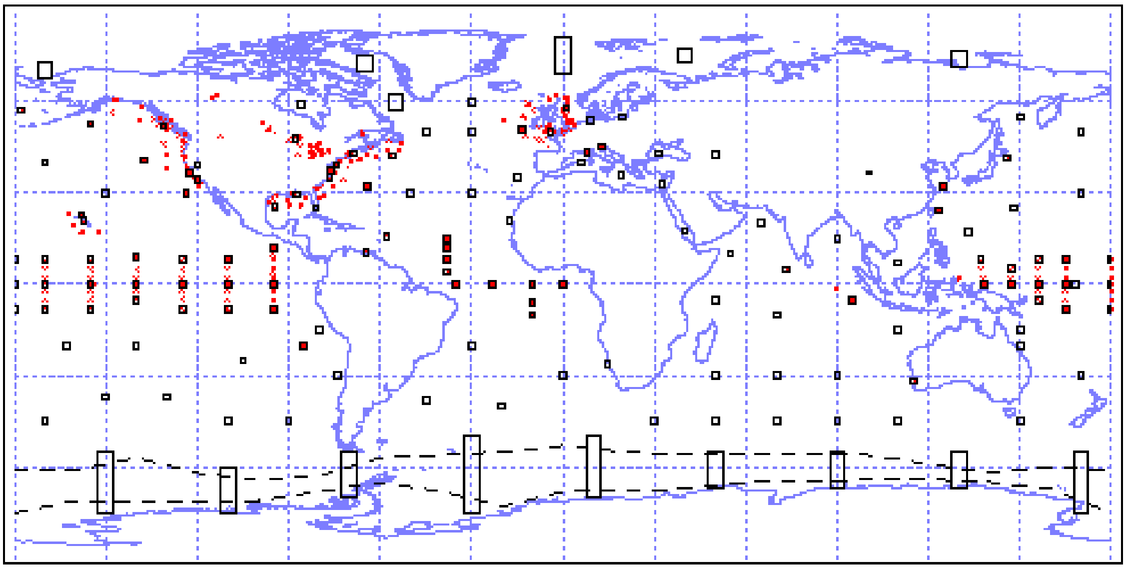


Figure 4.10.1 Version 2 HR-DDS locations based on Science Team feedback at the 2nd GHRSST-PP workshop.

Donlon suggested that the following list be considered a 'Critical data requirements' list for all HR-DDS sites (although this was not a closed list):

- NOAA AVHRR (SST and if possible, brightness temperature)
- AATSR (SST and if possible, brightness temperature)
- MSG-SEVIRI (SST and if possible, brightness temperature)
- GOES-E (Specific Channels)
- GOES-W (Specific Channels)
- GMS (Specific channels)
- AMSR/AMSR-E (SST, Surface Wind Speed, Columnar Water Vapor, Cloud Liquid Water)
- SSM/I (Surface Wind Speed, Columnar Water Vapor, Cloud Liquid Water)
- TRMM TMI (SST, Surface Wind Speed, Columnar Water Vapor, Cloud Liquid Water)
- TAO/PIRATA (SST, wind speed)
- Solar radiation....
- SSTskin in situ (MAERI, ISAR, CIRIMS, Research cruises)
- MW SST in situ

Clearly, data provision and access must be negotiated with data providers but these requirements should form part of any major project initiative towards the implementation of GHRSST-PP.

Donlon then provided an overview of the functionality of the HR-DDS system. Figure 4.10.2 provides a functional diagram of the major components of the HR-DDS system.

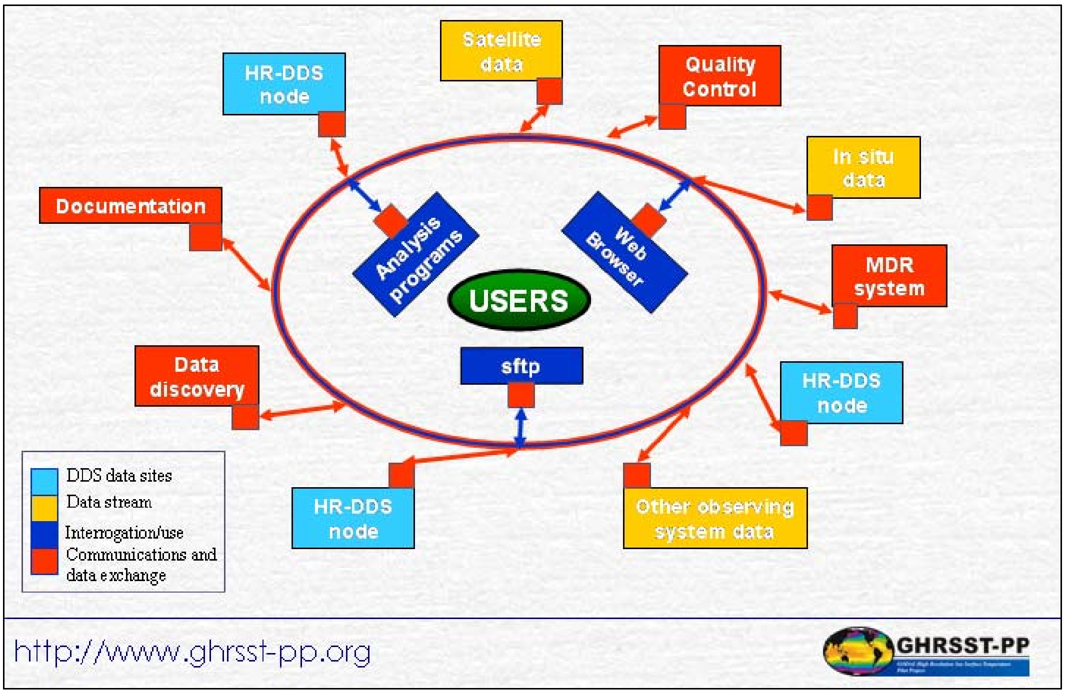


Figure 4.10.2 Major components of the GHRSST-PP HR-DDS.

In order to take full advantage of tools such as DODS/LAS/OPeNDAP, it is proposed that the HR-DDS file format is netCDF (v3.0). This provides multi-dimensional array storage capability and self describing data format containing exact metadata or ASCII text. Point time-series data can be represented as a 2-D table (e.g., buoys).

Data transport is through OPeNDAP "middleware" and sftp. A web browser user interface will be developed as an initial solution but as a phase 2 solution a direct query command line interface is highly desirable to facilitate the extraction of large numbers of data.

Quality control tools to facilitate inter-comparisons, differences statistics could be developed in line with the work of the GODAE data sharing project. Data assembly and archive will be at a number of different locations ("HR-DDS nodes").

Within the model, metadata management is a critical issue and it is proposed that HR-DDS metadata is based on the GCMD and Climate Forecast ("CF") conventions using XML as a data receptacle. This is Compatible with GODAE Data Sharing (DS) pilot project, OPeNDAP/LAS/DODS and already has extensive and freely available data analysis tools. Furthermore it is adopted by most major oceanography programs

A two tier approach to metadata management is proposed based on a single Data Set Record that contains information which is common to many data granule files within the data set, such as the title and contact information. Data granules are then described by many file record that contains the information that distinguishes each file from all others within the data set.

GHRSST-PP currently suggests that data archive should take place at regional nodes. In order to index such a distributed system, a master metadata repository must be developed and automated procedures for the submission of metadata are required. It is proposed that this forms part of the GHRSST-PP central metadata repository. Such a model provides great flexibility for data discovery and administration functions. Figure 4.10.3 provides a functional diagram of a GHRSST-PP HR-DDS node and interactions with users and the HR-DDS master metadata repository.

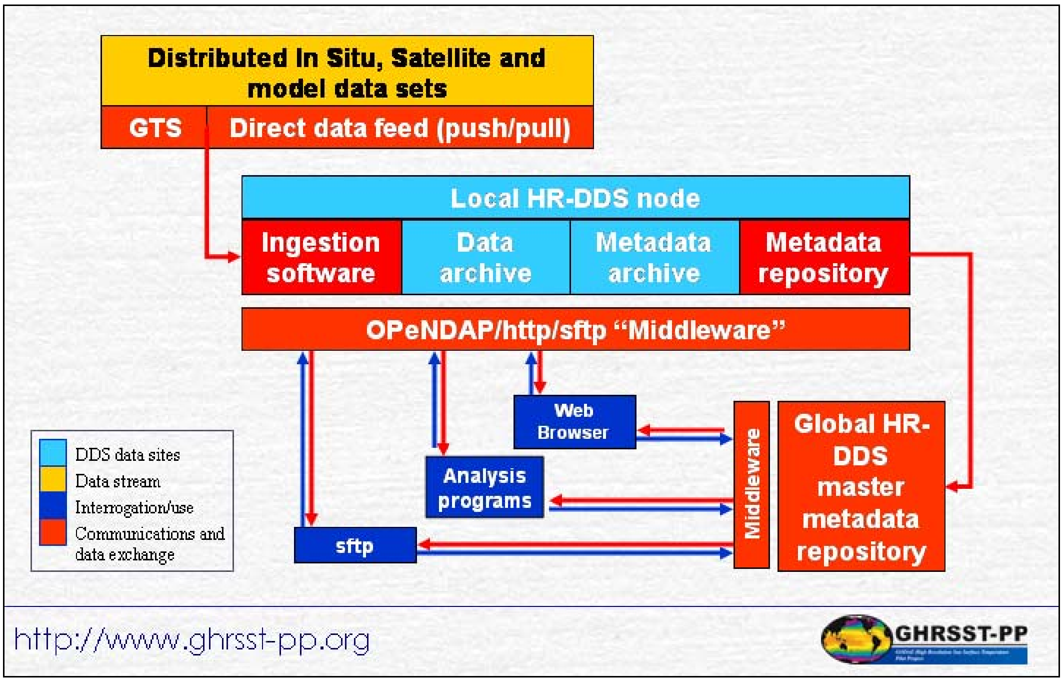


Figure 4.10.3 Schematic functional diagram of a GHRSST-PP HR-DDS node.

Donlon concluded that GHRSST-PP HR-DDS system implementation plan draft has been made available to the community for comment. This forms the master reference document at present. A pilot implementation of the HR-DDS system will be complete by the end of 2002 at the JRC in collaboration with PO.DAAC who are working on a master metadata repository. Critical parameter data population should begin by the end of 2003 as an initial test exercise. Users should register on the system and start to use the system in early 2004. Additional RDAC HR-DDS systems should be installed after acceptance tests are complete. This plan of action would achieve the priority action identified at the Tokyo meeting.

4.11 A. Harris: The GDAC Data Product Computation Facility (DPCF)

No abstract available

4.12 H. Kawamura: Japanese research plans towards the satellite/in situ GHRSST-PP network

Hiroshi Kawamura explained that a New SST Development Strategy was initiated in 2000 that focused on developing a contribution to GODAE and demonstrate its efficiency to the potential oceanographic user community. This developed a cloud-free high-resolution daily BULK-SST. The First phase of the project runs between 2000-2003 and the release of the first data products (NGSSTv1) was released in July 2001.

With support from the user community in Japan, a second phase of the project is now underway. In this part of the project the emphasis is to develop more advanced products by conducting the physical and technological research on the bulk-skin temperature difference and diurnal effects. This second phase will run between 2002-2005 and a experimental cruise is planned for FY2003 aboard the Japanese R/V "Mirai". Figure 4.12.1 provides a schematic overview of the key scientific elements second phase of the NGSST project.

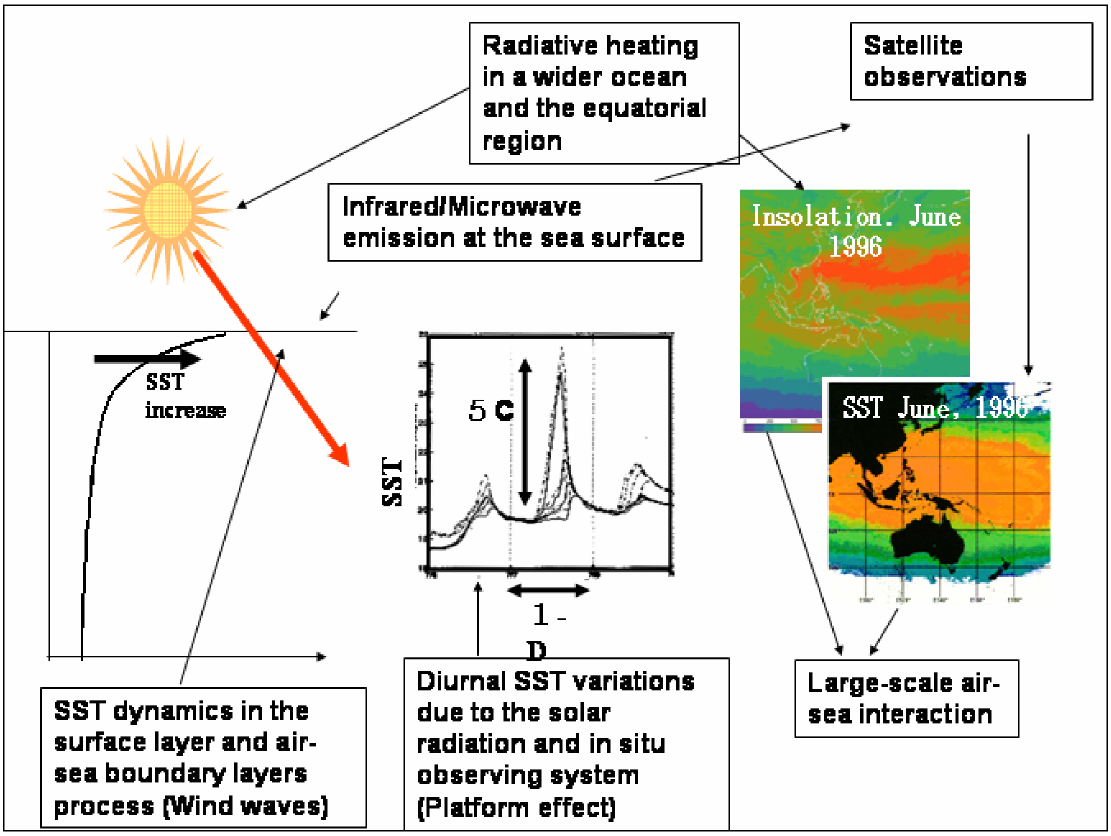


Figure 4.12.1 Key components of the second research phase of the new generation SST project (H. Kawamura).

Kawamura then explained that a significant data set had been collected in Japan in the Mutsu Bay area of northern Honshu by a joint Japanese-English team in 1995-1997. This data set had not yet been fully analysed but since one of the key japans e researches within the Mutsu bay experiment (Dr S. Tanba) was now working with the NGSST group, the data set can be revisited. In particular, the Mutsu Bay data are extremely interesting for diurnal variability studies. This is seen in satellite data of the area (Figure 4.12.2) where thermal IR data show a warming while visible channel observations suggest a calm surface with little wind.

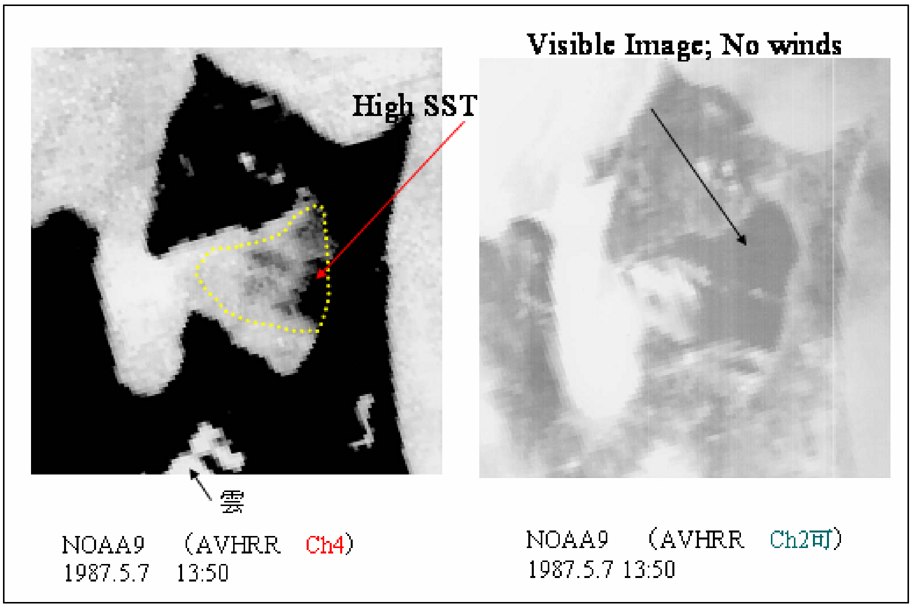


Figure 4.12.2 AVHRR satellite measurements in the Mutsu Bay area showing a clear diurnal warming signal using infrared and visible channel data. (H. Kawamura)

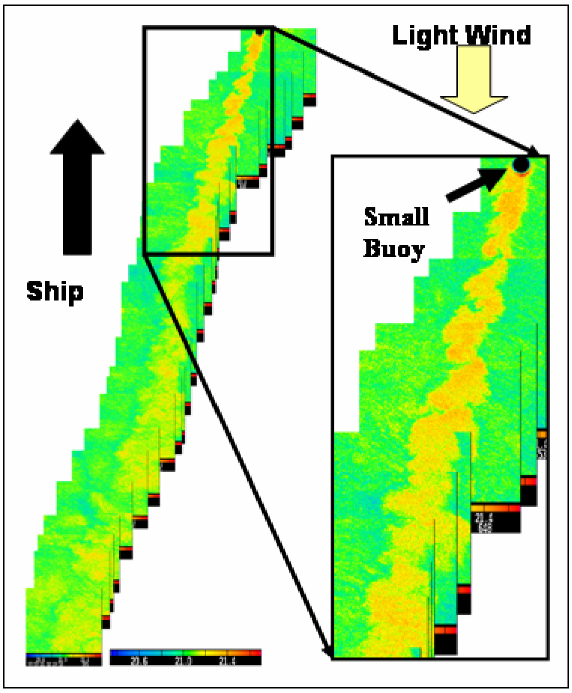


Figure 4.12.3 Thermal camera observations of the sea surface collected during the Mutsu Bay Campaign. In this sequence, the thermal wake behind a small buoy is shown. (H. Kawamura).

During the Mutsu Bay campaigns many infrared radiometer systems were deployed together with in situ SSTdepth sensors in order to (a) validate satellite measurements and (b) to investigate the dynamics of the thermal characteristics of the ocean skin. Instruments. Thermal infrared camera systems provide an enormous set of data that will be used for this purpose (see Figure 4.12.3).

Finally, Kawamura showed examples of coupled ocean-atmosphere modelling work in the Mutsu Bay area (see Figure 4.12.4) that is capable of resolving clear diurnal signals. A 24 layer (10km height) atmospheric model is coupled to a 53 layer (30m depth) ocean model in the Mutsu Bay area. In addition, a 5 layer land model is used to provide inputs to the system. The system is now being used for experiments in the Mutsu Bay area and will provide a background focus to all satellite and in situ data analysis.

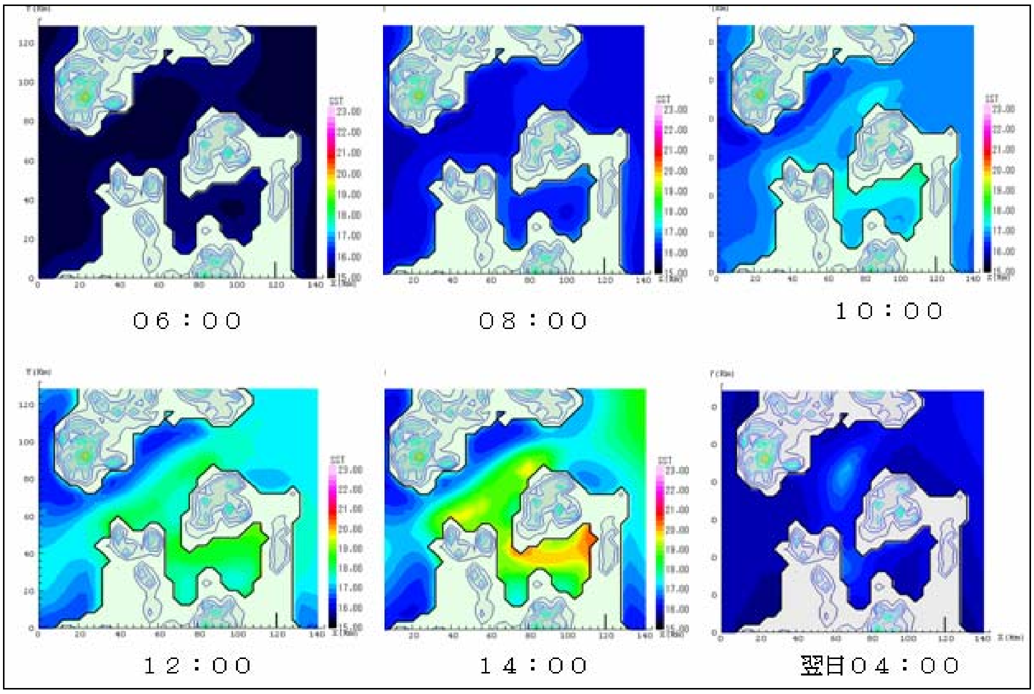


Figure 4.12.4 Example of diurnal warming in the Mutsu Bay, Japan modelled by the new ocean-atmosphere-land coupled models developed by the University of Tohoku. (H. Kawamura)

4.13 G. Wick: In situ and Satellite Data Integration (ISDI). First report of the Technical Advisory Group (ISDI-TAG)

Gary Wick reported on the discussions that have taken place since the last GHRSST-PP workshop within the In situ and Satellite Technical Advisory Group (ISDI-TAG). The current membership of this GHRSST-PP working group was set up shortly after the Tokyo GHRRST-PP meeting as follows:

- G. Wick (chair)
- Hiroshi Kawamura
- Yoshimi Kawai
- Pierre LeBorgne
- Chelle Gentemann
- Doug May
- Craig Donlon
- Simon Pinnock
- Andy Harris
- Ed Armstrong

The main Terms of reference for the group were to:

- Develop consensus methodologies for provision of SSTs within RDACs and GDAC
- Form an international panel to oversee:
    - Product format
    - Validation protocols

    - Data archival
- Review and assess proposals for improvements to methodology
- Review and assess experiments at GDAC

The ISDI TAG have now published a working report on the initial discussions (available at the GHRSST-PP web site). The major conclusions form the working group are:

1. Skin, subskin and a constant temperature layer (currently referred to as a foundation temperature) data products should be produced by the GHGRSST-PP.
2. Two types of data products should be derived from multiple data sources. Merged data products and Analysed data products.
3. Merged data products should be derived from the best retrievals of each depth quantity for each different sensor type mapped onto a common grid. There should be no 'gap filling' using synthetic data of any kind. The original sensor error characteristics must be preserved. 6 hourly fields at 0000, 0600, 1200, and 1800 UTC should be produced. No conversion to specific analysis time should be made and the spatial resolution should be to better than 10 km.
4. Analysed products will use analysis procedures to fill in gaps in sensor coverage and account for differences in sensor calibration. Daily values will be used in the absence of diurnal warming information which requires adjustment to all retrievals. Diurnal information will be added as a separate field to the product and should include amplitude, the time of peak warming and an uncertainty measure as a minimum.
5. Skin data products should be derived from IR sensor products and MW products converted to skin where appropriate.
6. Sub-skin data products should be derived from MW products and IR skin products converted to sub-skin where appropriate.
7. As a working definition of the foundation temperature (formerly termed the constant later temperature), these data products should be derived from SSTsubskin and include a solar heating correction term to account for diurnal variations.
8. Product confidence statistics should provide an estimate of uncertainty derived during product generation. This includes bias and standard deviation values for each grid cell. These should be derived from validation of similar quality recent measurements against direct observations. In addition, the group suggest that additional confidence flags are derived for each pixel including (for example) the number of retrievals, sensor type, cloud type, etc.
9. Error statistics should be derived fro direct validation of products following recovery of all direct measurements. They must include a bias and standard deviation and provide global representation on a monthly timescale at a minimum.
10. For skin to sub-skin conversion, the group recommend that the parameterization of Donlon et al. (2002) and the parametric model of Fairall et al. (1996) are used. These should be run in parallel and evaluated for consistency.
11. For diurnal Warming Corrections, the empirical procedure described by Gentemann et al. (2002) should be used and the use of numerical model methods should also be investigated (e.g., Kawai and Kawamura, 2000).
12. Data merging procedures should use a single value per sensor, per grid point, per time interval. Averaged SSTs with no required diurnal correction and highest confidence level are acceptable. Only data with the highest confidence level should be used and ranked according to the smallest diurnal correction that was applied.

13. The recommended analysis procedure is optimal interpolation based on Carter and Robinson (1987) and Reynolds and Smith (1994). The procedures incorporate sensor bias adjustments prior to analysis.
14. For validation of data products, the group noted that independent direct observations should be used to greatest extent possible. In all cases, there must be an effort to avoid the use of relationships between product depths.
15. When treating data of different spatial scales a coarse resolution data should be applied to all corresponding grid cells and averaging may be required for finer resolution data.
16. The recommended data product formats are based on user convenience and consistent with archival centres and data exchange protocols. These include HDF, NetCDF, and BUFR in keeping with the JPL PO.DAAC final archive centre.

The ISDI-TAG group has requested that additional expertise is brought into the group in the following areas:

- User applications
- Sea ice
- and possibly inputs having a coastal area focus
-

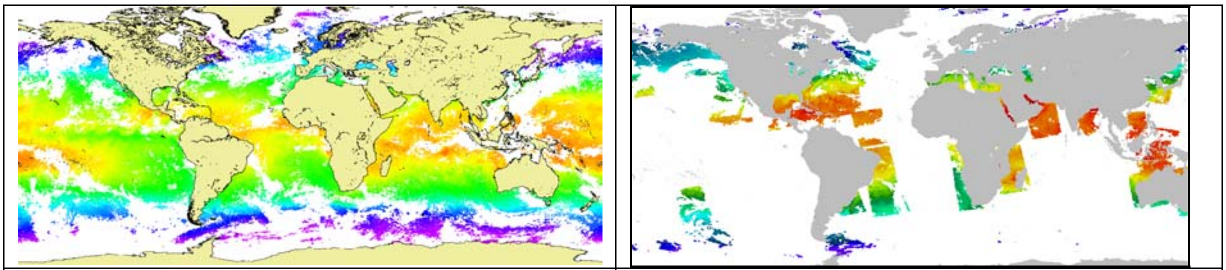
The ISDI-TAG group remains active and should report at the next GHRSST-PP workshop.

5 Session 3: Data Access December 3rd

This session, chaired by Chelle Gentemann, was dedicated to reviewing some of the issues facing the GHRSST-PP in terms of data availability and data access.

5.1 D. May: NAVOCEAN data and the GHRSST-PP

Doug May presented a review of the potential contributions and expectations for GHRSST-PP by the Naval Oceanographic Office (NAVOCEANO). May began by describing the data products that were produced at NAVOCEANO on an operational basis. The primary data products is the AVHRR MCSST product provided on an 8km spatial scale and is a SSTdepth retrieval. Approximately 320,000 retrievals are made per day and the data products are available with a time delay of less than 3-4 hours from acquisition. Figure 5.1.1(a) provides an example of a typical GAC MCSST map provided by NAVOCEANO.



(a) (b)

Figure 5.1.1 (a) Example AVHRR MCSST 8km GAC product provided by NAVOCEANO. (b) Example AVHRR MCSST LAC 2km product provided by NAVOCEANO (D. May)

In addition to the GAC MCSST data product, a Local Area coverage (LAC) MCSST data product is also computed (Figure 5.1.1(b). This has a nominal resolution of 2km and consists of over 1 million retrievals per day. Each LAC MCSST data product is made available within 3-4 hours of data acquisition. Finally, daily GOES MCSST data products are also provided. These have a resolution of 12km derived from 4-6 million retrievals each day. These data products are made available within 1 hour of data acquisition (Figure 5.1.2).

In summary, for the 2003-2005 GHRSST-PP time period, NAVOCEANO will provide the following SST data sets to the GODAE server for use within the GHRSST-PP:

- 8km AVHRR GAC MCSSTs (N-16 and N-17)
- 2km AVHRR LAC/HRPT MCSSTs (N-16 and N-17)
- 12km GOES-East MCSSTs
- 12km GOES-West MCSSTs

In addition, NAVOCEANO can also supply a 10km analyzed field every 24 hours.

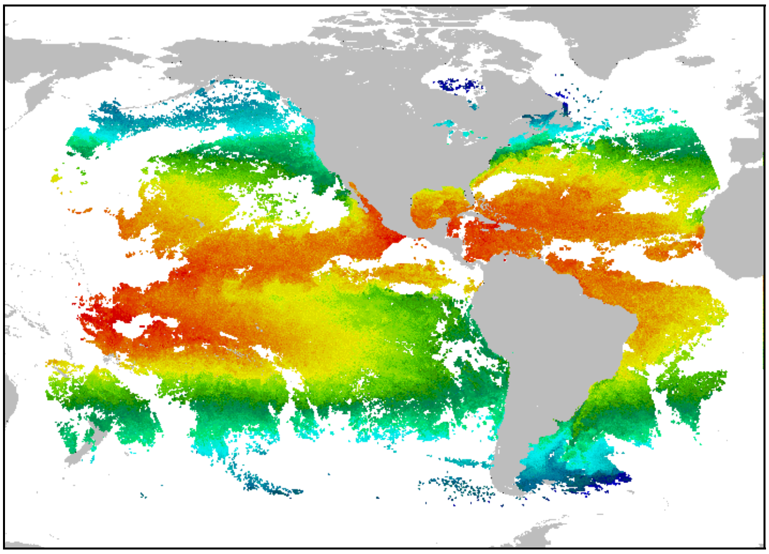


Figure 5.1.2 Example NAVOCEANO GOES MCSST 12 km data products (D. May)

May then described the SST retrieval error estimates that are computed at NAVOCEANO for each satellite data product. Each SST retrieval data record contains an RMS error estimate that provides data error estimate for analyses/models to utilize within their assimilation weighting schemes. The procedure is based on a statistical relationship between a time series of several instrument and analysis parameters and in situ observations. These are related to a mean absolute error estimate in °C. The error estimates are monitored daily and updated regularly. Table 5.1.1. provides an example of the error estimates and the percentage of data that fall into one of three categories:

- Clear
- Probably clear and
- Questionable.
-

The procedure is relatively simple but works well. May noted that in principle, the NAVOCEANO scheme is similar to the French SAF scheme presented by P. Le Borgne (see section 7.9).

Table 5.1.1. Example error statistics computed for the N16 AVHRR.

N16	Daytime	Nighttime
Clear	0.45(86-90%)	0.40(97-98%)
Probably Clear	0.65(10-12%)	0.75(1-2%)
Questionable	1.50(1-2%)	1.50(<1%)

May then described the expectation that NAVOCEANO has from the GHRSST-PP in return for access to NAVOCEANO data. NAVOCEANO desires near real-time access to other satellite SST data sets via GODAE to assimilate into operational nowcasts/forecasts. The following data sets are requested:

- From Europe - AATSR (1km polar), MSG (4km geostationary)
- From Japan - GLI (1km polar), MTSAT (4km geo), AMSR-E (50km polar)
- From other groups - AMSR (50km polar), MODIS (1km polar)

These data sets will complement the AVHRR GAC SST data which is the only data currently assimilated into the Navy analyses/models. By assimilating other polar orbiting data and geostationary data it is expected that there will be improvements in the timeliness and accuracy of model nowcasts and forecasts. Furthermore, the use of higher resolution SST data has considerable impact on several model fields as shown in Figure 5.1.3.

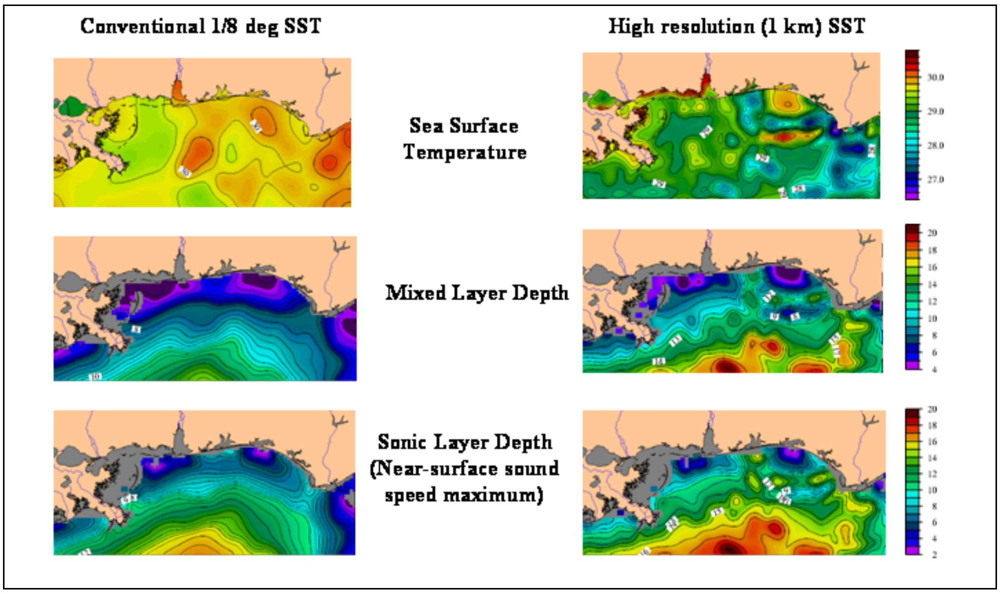


Figure 5.1.3 The impact of assimilating high resolution SST data on model SST, Mixed Layer Depth and sonic layer depth (D. May).

May then noted that NAVOCEANO could also contribute to the validation of GHRSST-PP data products. NAVOCEANO operationally generates accuracy statistics for each satellite SST data set on a continuous basis.

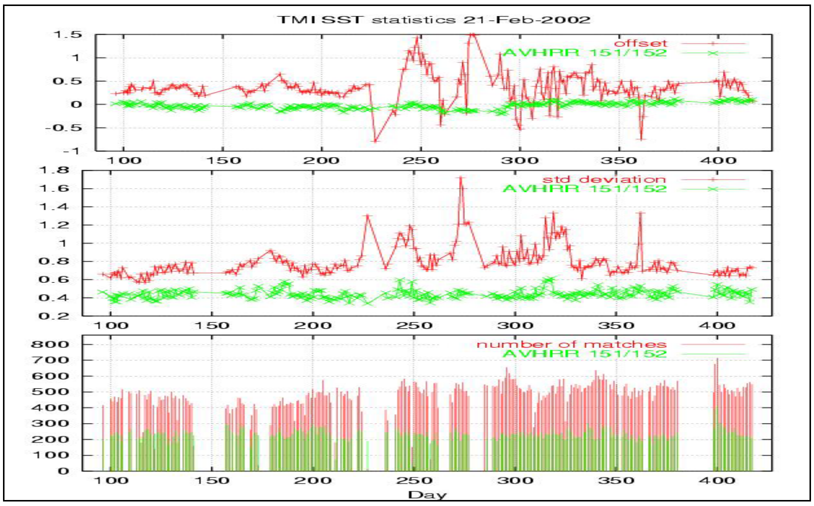


Figure 5.1.4 Validation of TRMM TMI data and computation of error statistics at NAVOCEANO for 21st February 2002. (D. May)

Satellite SSTs are matched to drifting buoy and moored buoy SSTs within 4hr and 25km. Only the closest match is retained for statistical calculations. Statistics are generated once per week using the latest 4 weeks of match-ups (see Figure 5.1.4)

May then noted that the NAVOCEANO SST production process is robust and can readily implement new equations, algorithms, and processing steps successfully demonstrated by GHRSST-PP. NAVOCEANO is interested in the sustainability of SST data exchange server beyond 2005 and thus has a keen interest in the GHRSST-PP.

5.2 M. Petit: The SEASnet program and the GHRSST-PP

Michell Petit explained that the Survey of the Environment Assisted by Satellite (SEAS) is a regional project pioneering advanced technology for the survey of the inter-tropical zone using earth observation satellites. The project has a wide base of participants from France and several developing countries that uses independent data sources to compute near real time maps of satellite data products including SST. The aims of the project are for a long-term system of observation that uses a generic methodology and encourages the participation of users, managers and scientists in all aspects. Petit noted that these aims were identical to those of GHRSST-PP and that the SEAS project can contribute to the GHRSST-PP in many ways.

SEAS coordinates (by federation) the routine operations at several AVHRR LAC receiving stations shown in Figure 5.2.1.

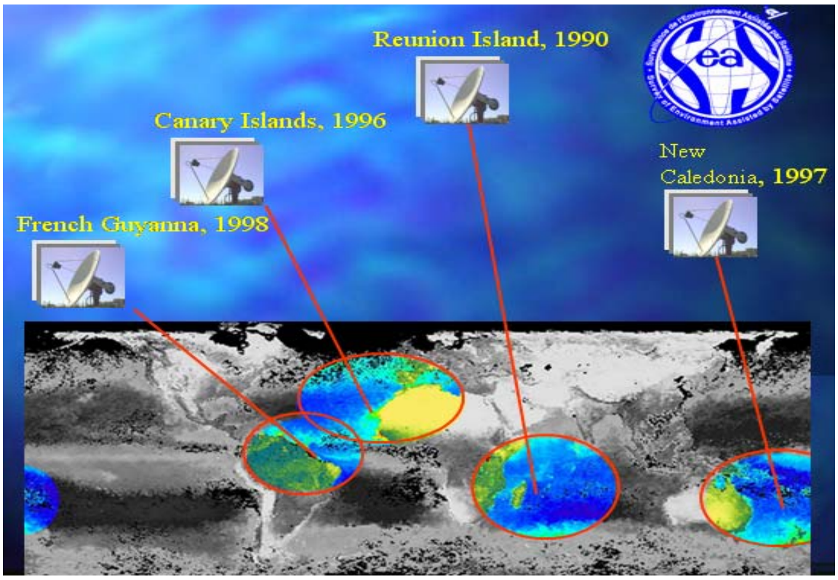


Figure 5.2.1 Location of the SEASnet receiving stations (M. Petit).

SEAS helps to transfer technology and to share common problems/developments across the seas network (SEASnet).

Within SEAS, SST, ocean colour and altimetery products are generated at each node of the SEASnet and are shared across the network using a system called the *Antenne Virtuelle Intertropicale* (Inter-tropical Virtual Antenna) or AVI project. In this project real time data are received and processed at each node of the network but controlled remotely. In addition, the project undertakes a normalized data archival at a central location, and maintains a data base distribution of all data products that are disseminated by the network in near real time.

The AVI data processing and data sharing network is shown in Figure 5.2.2. The AVI system is designed to receive data in near real time from each receiving station that are transferred via ftp to one of two server systems. This is controlled by a remote operator. Data are then transferred to a data merging processor that computes and disseminates data products to users via an http interface.

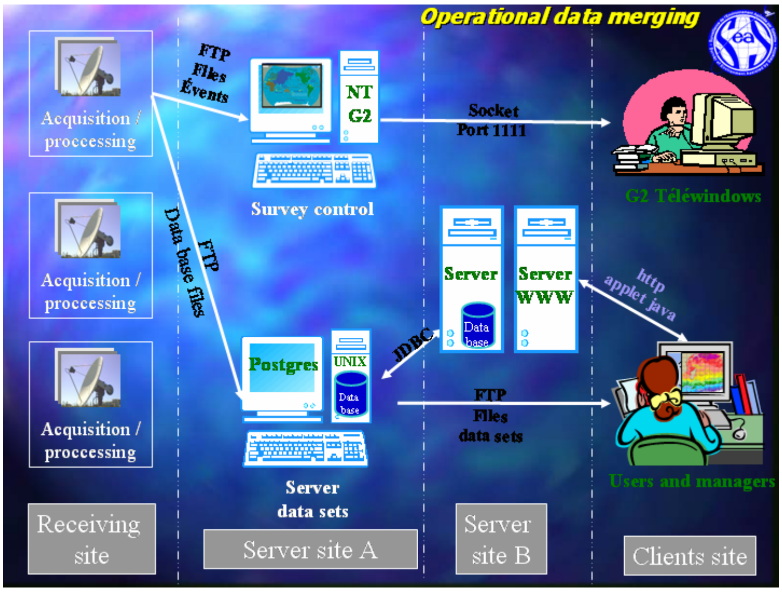


Figure 5.2.2 A schematic diagram of the AVI network. (M. Petit)

Petit proposed the SEASnet program as a GHRSST-PP Tropical RDAC centre that can help to manage AVHRR LAC data coverage. Furthermore, SEASnet is interested in working together with GHRSST-PP to trial new SST merging procedures and algorithms.

5.3 H Kawamura: The NASDA GHRSST-PP data server

Hiroshi Kawamura gave a summary of the history of the ADEOS-II mission design and implementation phase noting that operational oceanography was not a priority when the mission was first proposed in the early 1990's. This has implications for the development of an operational real time data service now proposed by GODAE. A new data management and dissemination framework is required for GODAE and GHRSST-PP. Within NASDA there are two key agencies that are working on the ADEOS suite of algorithm developments:

- EOC: Earth Observation Center responsible for the operational Data Processing and Distribution
- EORC: Earth Observation Research Center responsible for R&D, Demonstration operation

Kawamura noted that these groups had stringent plans for ADEOS-II. A version 1 set of algorithm/software will be delivered from EORC to EOC +6 months after the launch. NASDA/EOC will then deliver the initial products for public 12 months (+9 months expected) after the launch. This is a fixed timetable and there is little scope for alteration for the purposes of GODAE and GHRSST-PP. Figure 5.3.1 summarizes the data processing schedule for AMSR-E Data products that clearly identifies an operational time delay of 230 minutes for real time data delivery of SST products. In a normal operating mode, the time delay is at least 440 minutes.

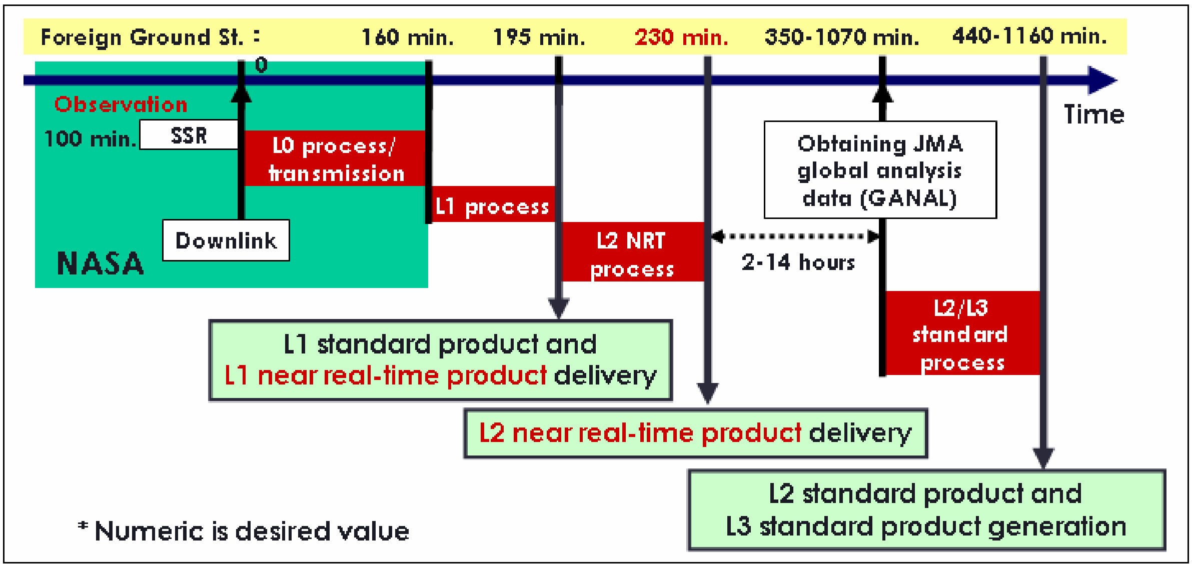


Figure 5.3.1 Data processing schedule for AMSR-E data processing (H. Kawamura).

Kawamura explained that the Global Imager (GLI) data flow is far more complex and as the data volume is enormous there would only be a limited scope for near real time data access at this time.

In order for GHRSST-PP to gain access to NASDA ADEAOS-II data products, a dedicated GHRSST-PP data server will be provided. Within this system, it is planned to make AMSR-E products available to anybody in May 2003 although AMSR-E SST will be available for GODAE users in December 2002. The server has been developed in EORC and will thus have considerable data access possibilities. In particular, global AMSR/AMSR-E and regional GLI SSTs are generated at EORC in real-time and these will be made available on the GHRSST-PP server.

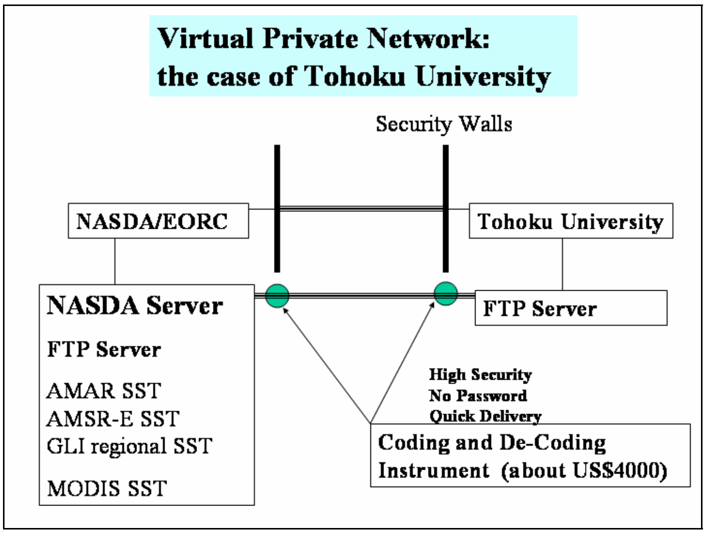


Figure 5.3.2 the proposed Virtual Private Network Server solution for the NASDA server for GODAE/GHRSST-PP. (H. Kawamura).

As an initial proposal, EORC suggest that SST products are transferred through the NASDA Virtual Private Network (VPN) to the operational users in order to guarantee quick, easy and safe data transfer to the operational users (see Figure 5.3.2). This will mean that the user must install a decoder unit at their location costing about $4000USD. For other R&D users (PIs) SST products of few-days can be accessed through the WEB using the PIs password. It is proposed that the GHRSST-PP Science Team are all given PI status and are thus able to gain access to the data server.

5.4 C. Donlon: The ESA Category I proposal for access to ESA data within the GHRSST-PP

Craig Donlon presented an overview of the GHRSST-PP Category 1 data access proposal that had been submitted to ESA. The ESA Category 1 system provides access to ESA data at the cost of media only and provides a convenient method for the GHRSST-PP Science team to gain access to AATSR and other ESA data holdings in near real time. The primary aim of the proposal is to ensure the effective provision and use of AATSR SST and RA-2 wind/wave data products within the GHRSST-PP. The main objectives are:

1. To establish and operate data access, timely data exchange routes, protocols and services
2. To characterise the quality of AATSR SST and RA-2 wind data through validation exercises and identify differences within the GHRSST-PP DDS.
3. To use AATSR/RA-2 data streams within the GHRSST-PP ISDI and the DUP-2 "Medspiration" project.
4. To fully exploit AATSR/RA-2 wind/wave data products to provide a new generation of high-resolution GHRSST-PP SST data products

The proposal specifically requests access to the following data sets:

- AATSR:
  - i. 1km data (DDS, coastal and UHR data sets)
  - ii. 10 arc minute data
  - iii. Average SST (ASST)
- RA/2 Altimeter wind/wave data
  - i. Fast delivery (FDGR)wind/wave products
- 3rd party missions (AVHRR/MSG/MODIS...)
  - i. SST

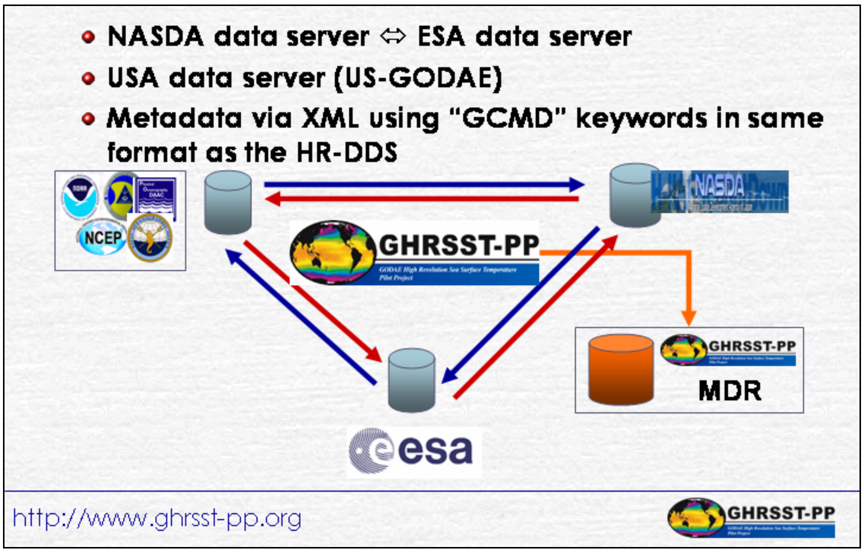


Figure 5.4.1 Key data servers within the GHRSST-PP.

Donlon noted that there was a need to ensure that GHRSST-PP data servers were coordinated and able to exchange data in near real time. This is a considerable challenge given the relatively large volumes of data that these systems must consider. Figure 5.4.1 shows a schematic overview of the key data servers within GHRSST-PP. the

GHRSST-PP Master Metadata Repository system (MDR) forms the index for all data holdings at each server node allowing users to search for data sets using generic metadata that should be submitted to the MDR as data are placed on the server.

During the GHRSST-PP preparation Phase (Nov 2002 - May 2003) the following actions should be complete:

- Install and test of ENVISAT and TPM (push or pull) servers providing data to the GHRSST-PP RDACs (European, Japanese and USA) .
- Install and test AATSR data distribution to RDAC and GDAC facilities for use in the development of GHRSST-PP data products.
- Installation of OPeNDAP (Former DODS) system at DDS host institutions(RDAC) for effective data exchange.

During the GHRSST-PP Operational phase (June 2003 until June 2006) the following actions are foreseen:

- AATSR and RA-2 Data provision for the European "Medspiration" DUP-2 project.
- Real time automatic delivery (either push or pull) to GHRSST-PP RDAC and GDAC facilities.
- Real-time automatic population of GHRSST-PP RDAC DDS with AATSR and RA-2 data.
- On-going validation and inter-comparison of AATSR data products within the GHRSST-PP DDS system.

The following deliverables are specified in the proposal:

- Demonstrate the international use of AATSR data to derive SST maps within the GHRSST-PP framework
- Participate in two dedicated AUS workshops:
    - "The application of GHRSST-PP data products in operational and research environments"
- Prepare a minimum of two peer reviewed journal articles describing the use of AATSR and RA-2 data within the GHRSST-PP.
    - One for the HR- DDS
    - One for the general use of AATSR in GHRSST-PP Operations/Products
- Make a contribution to other ENVISAT AO proposals making use of AATSR data.
- Provide 6 monthly reports and final report for the proposal.

At the workshop, ESA informed the workshop that the GHRSST-PP Category 1 proposal had been accepted and work will commence on organising AATSR data availability in the coming months. It was noted that there would be a delay as ENVISAT was still operating in a 'validation phase' and data are not available for general use at present. It was expected that AATSR data would be available in early 2003.

6 Session 4: Validation of GHRSST-PP Data products December 4th

This session, chaired by Ian Barton, provided a review of several validation activities that are relevant to the GHRSST-PP.

6.1 U. Send: In situ observations in the GHRSST-PP

Uwe Send provided an in depth review of current operational in situ SST infrastructure based on the needs of the GHRSST-PP that were stratified as:

- products (analyzed and re-analyzed SST)
- the diagnostic data set (verification, QC, etc)
- resolving the diurnal cycle

For SSTskin and to a great extent for SSTsubskin observations, dedicated and costly infrared and microwave radiometers deployed from buoys, ships are required which is both costly and immature in terms of the available technology. SSTdepth is the only SST parameter that can be measured operationally using current in situ technology and infrastructure. Send noted that In-situ bulk SST measurements used within the GHRSST-PP must consider the following issues for each type of data :

- **Accuracy:** better than 0.2°C
- **Frequency of sampling in space and time:** ideally several times per day, resolving diurnal cycles
- **Depths of measurements (incl. knowledge/definition of these):** 0.1 – 5 m depending on the conditions (i.e. influence of stratification)
- **Geographic distribution:** data are needed at the DDS reference sites but ideally with a global distribution.
- **Availability of the data**: ideally in real-time, but some delay is probably acceptable

The following operational SSTdepth data sources are available to the GHRSST-PP with each having a particular characteristic strength and weakness as shown in Table 6.1.1.

1. surface drifters
2. surface moorings (TAO/TRITON, PIRATA, Met Office buoys,...)
3. underway ship (SOOP,VOS, VOSCLIM) (xbt, thermosalinograph)
4. research vessels (CTD, XBT, ...)
5. profiling floats (Argo).

Table 6.1.1 Comparison between various SSTdepth in situ measurement systems.

Platform	Accuracy	Sample interval	Revisit time to DDS site	Sample depth	Coverage	Data availability
SOOP/VOS TSG lines	0.1K	> 4 weeks	> 4 weeks if located on a SOOP/VOS line	3-10m but disturbed by ship effects	Limited by commercial routes See Figure 6.1.1	Real time GTS
Surface drifting buoy	0.05 K	Hourly	approx. 10% of time, based on # of 2x2 boxes in ocean +/-60lat and 800 drifters	0.2-0.3m and 15m	Ice free ocean See Figure 6.1.2	Real time via GTS

Operational surface moorings	0.05 K	Hourly	Continuous if located on site	approx. 1m, sometimes also 10m, 20m	equator. Ocean, shelf seas, near continents	real-time (GTS)
PreOperational/Research moorings	0.05K	2-6 hours	Continuous if located on site	0.2-1m also 10m, 40m,other depths possible	see time series network shown in Figure 6.1.3	Real time via GTS
Profiling floats (ARGO)	0.005K	Typically 8 days	now 10% of time, for full array 50% of time (one float per 3x3 box on average)	5m min ! Below that high resolution (every m?) likely in 1-2years Iridium/Argos2)	ice-free ocean	Real time via GTS

Send concluded that most useful data source for diagnostic data set sites will be hi-frequency XBT lines (good near-surface sampling, reasonably frequent and regular) although the problem of accuracy may limit their applicability (especially in the top 5m). The workshop spent some time discussion the problems associated with XBT temperature sensors following the thermal delay on sensor elements following deployment from 'hot' ship decks into 'cool' seawater. Operational moorings (Atlas, Met Offices,...) offer good for routine 1m SST data but with no vertical resolution for diurnal cycle resolution/penetration. As a solution, GHRSST-PP should interface with time-series group to see which research/pre-operational moorings may be useable (HOT, BATS, ...), may provide what is required. GHRSST-PP DDS sites should be situated over these in situ facilities. Surface drifters will not always be available but can provide the missing information in high-latitudes, but only 20cm depth. Finally, ARGO floats will be difficult to use since current technology implementations limit to 5m depth and even in high latitudes a diurnal warm surface layer may be present - may complement single 1m data sources by adding vertical resolution for diurnal cycle

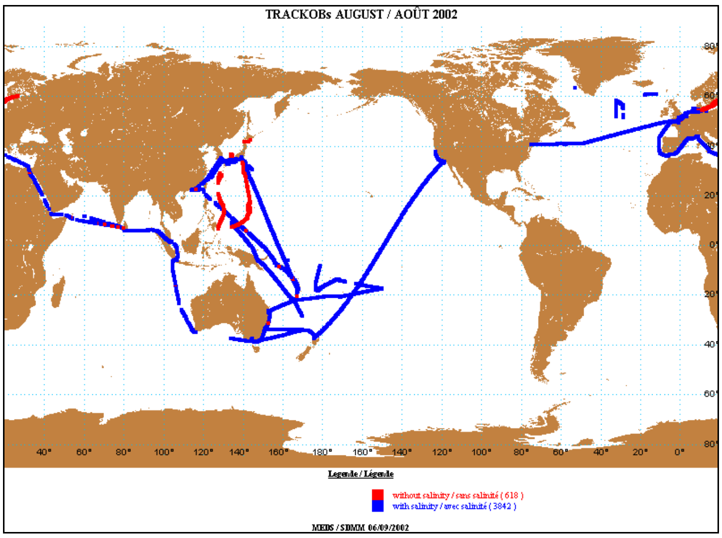


Figure 6.1.1 Thermosalinograph SOOP/VOS lines, August 2002. (U. Send)

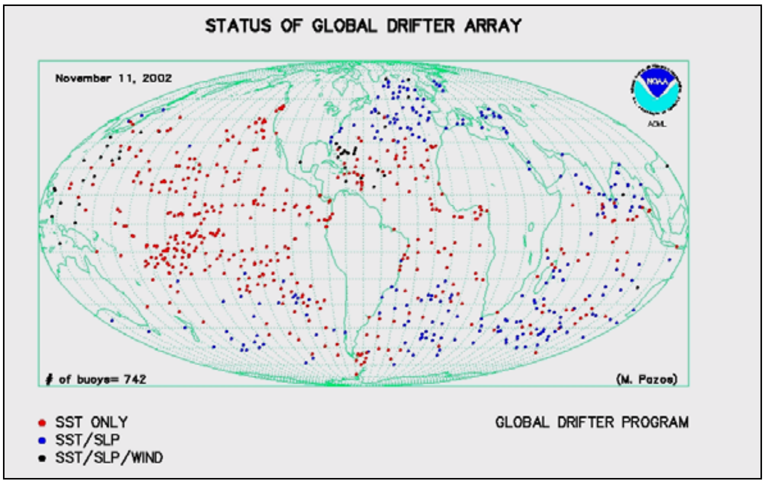


Figure 6.1.2 Global drifter array as of November 2002. (U. Send)

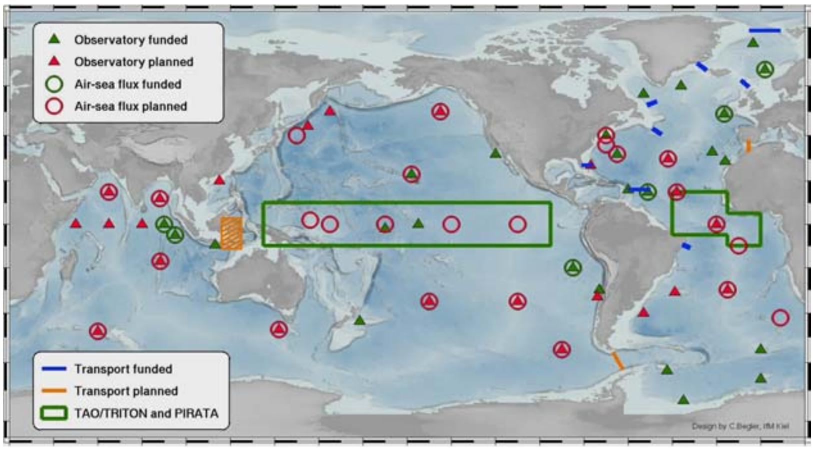


Figure 6.1.3 The proposed/planned time series surface marine network. (U. Send)

6.2 C. Gentemann: Calibration and Validation of AMSR-E: Early results

Chelle Gentemann began by explaining that significant calibration problems had been revealed in the AMSR-E hot load calibration sub-system. These were due to a change of design in the hot load target from a metallic construction to a composite structure with poorly defined thermal characteristics. The AMSR-E hot load uses 16 heaters operating on 4 different heater circuits to control the temperature of the calibration target itself.

Pre launch modelling of the hot load temperature characteristics describe smooth slowly varying signals over the course of an orbit whereas the actual situation is considerably different. Figure 6.2.1 shows a comparison of the expected temperature variation (panel a) together with the actual temperature variation (panel b). the thermal gradients across the hot load are more than was expected and the effect of heaters (located at approximately half the depth of the hot load pinnacles) switching on and off is apparent. It is proving difficult to model the thermal gradients across the surface of the hot load which is a particular problem as different feed horns of the AMSR-E view different parts of the hot load during calibration. Fortunately these problems were identified prior to launch and a rapid fix remedy was implemented consisting of two precision themistors that have been attached to the surface of the hot load. However, the use of these additional devices is still under investigation.

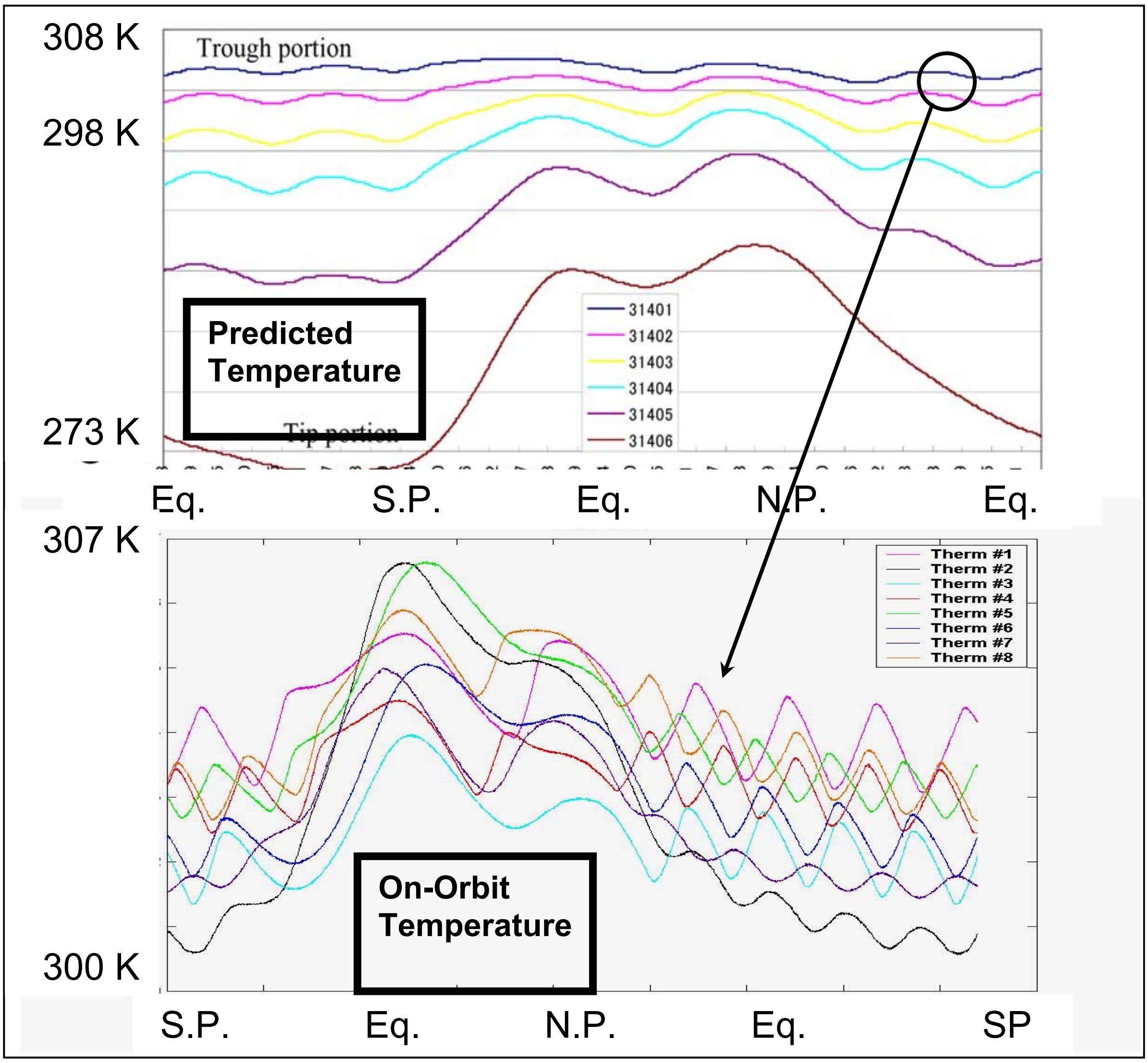


Figure 6.2.1 (a) Pre launch model of the AMSR-E hot load temperature characteristics. (b) In flight temperature characteristics of the hot load. Note the ~90° phase shift between panel a and b. (C. Gentemann)

Due to these problems, an alternative calibration strategy for the AMSER-E is required. The proposed scheme uses a deep space observation at 2.7 K and a suite of earth temperatures collocated with other satellite data (e.g., TMI) to model the hot load calibration. The scheme is now under investigation. Residual errors are still present due mainly to the effects of spill-over and viewing the moon by the cold mirror (used to obtain a deep space view. These are shown in Figure 6.2.2.

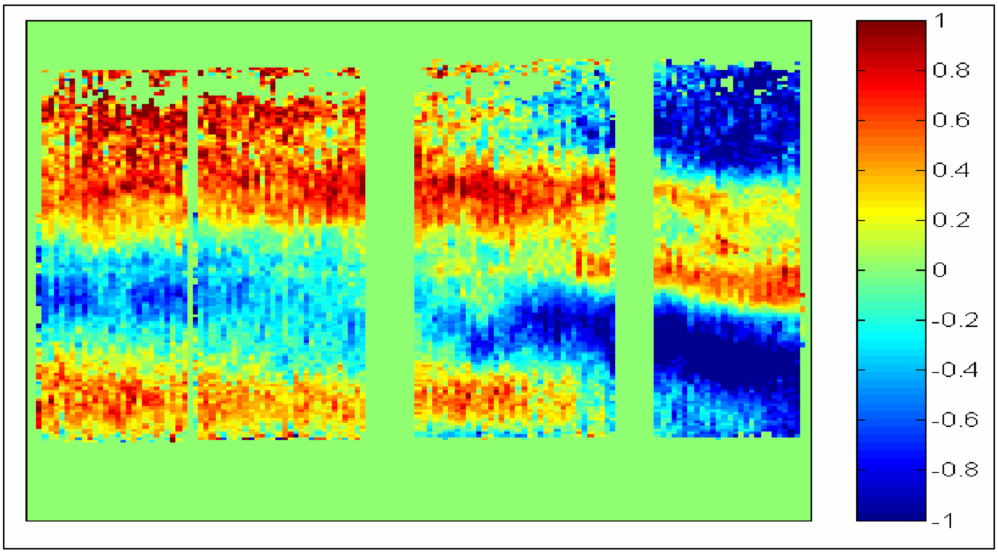


Figure 6.2.2 Residual calibration effects due to AMSR-E hot load problem. The plot shows the Zonal Average of Day Minus Night SST Difference as a Function of Time. X-axis covers the period 1-June – 15th October 2002. y-axis covers 90S-90N. (C. Gentemann).

Preliminary validation of AMSR-E SST using Reynolds SST which results in an rms. value of 0.76°C over the global ocean with a small bias. Comparison between TMI SST and AMSR-E SST has an rms.= 0.71 but with some regional differences, mostly relating to the edge of the TMI swath and in high wind speed areas where the microwave SST algorithms require correction for directional roughness effects. Current activities are focused towards re-deriving the hot load coefficients with a moving time window possibly using day/night coefficients. A version 2 algorithm is expected shortly. Gentemann finished with a number of example image data sets form the AMSR-E that highlighted the increased coverage possible using microwave radiometers to measure SST (See Figure 6.2.3).

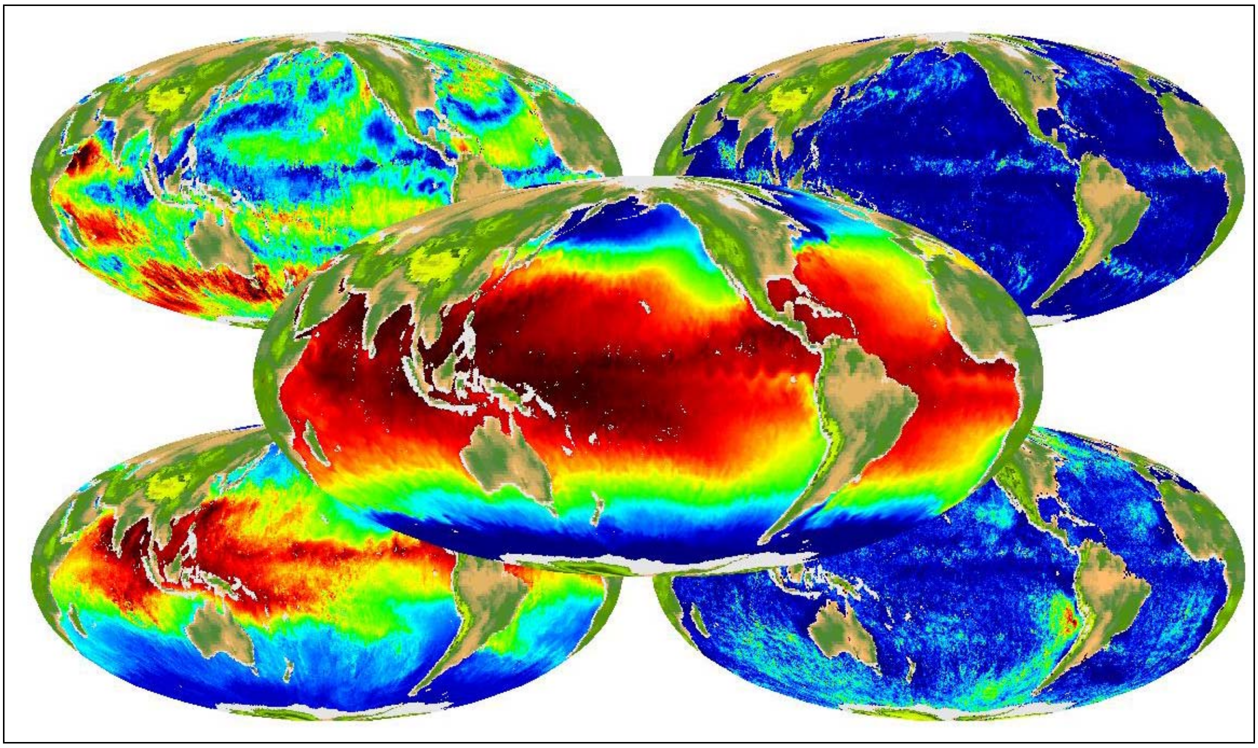


Figure 6.2.3 Example data products from the AMSR-E radiometer. Top left: surface wind speed. Top right: rain rate. Bot. left: water vapour. Bott. Right: cloud liquid water vapour. Centre SST.(C. Gentemann).

6.3 P. Minnett: Validation of satellite SST using MAERI data

Peter Minnet explained that validation of satellite data was required for three main reasons:

1. The need to know whether infrared atmospheric correction is working as anticipated. This requires high accuracy measurements, confidence in pre-launch calibration and characterization, and on-orbit calibration procedures.
2. The need to know error characteristics of the derived SSTs based on wide ranging measurements.
3. the need to know whether time-dependent degradation of the spacecraft sensor is occurring requiring measurements over whole period of mission.

Minnett explained that the thermal situation in the upper few meters of the ocean is extremely complex using observations obtained using the SkinDeep profiler system built by B. Ward. The time evolution of the vertical temperature profile can be extremely dynamic in certain regions (see Figure 6.3.1)

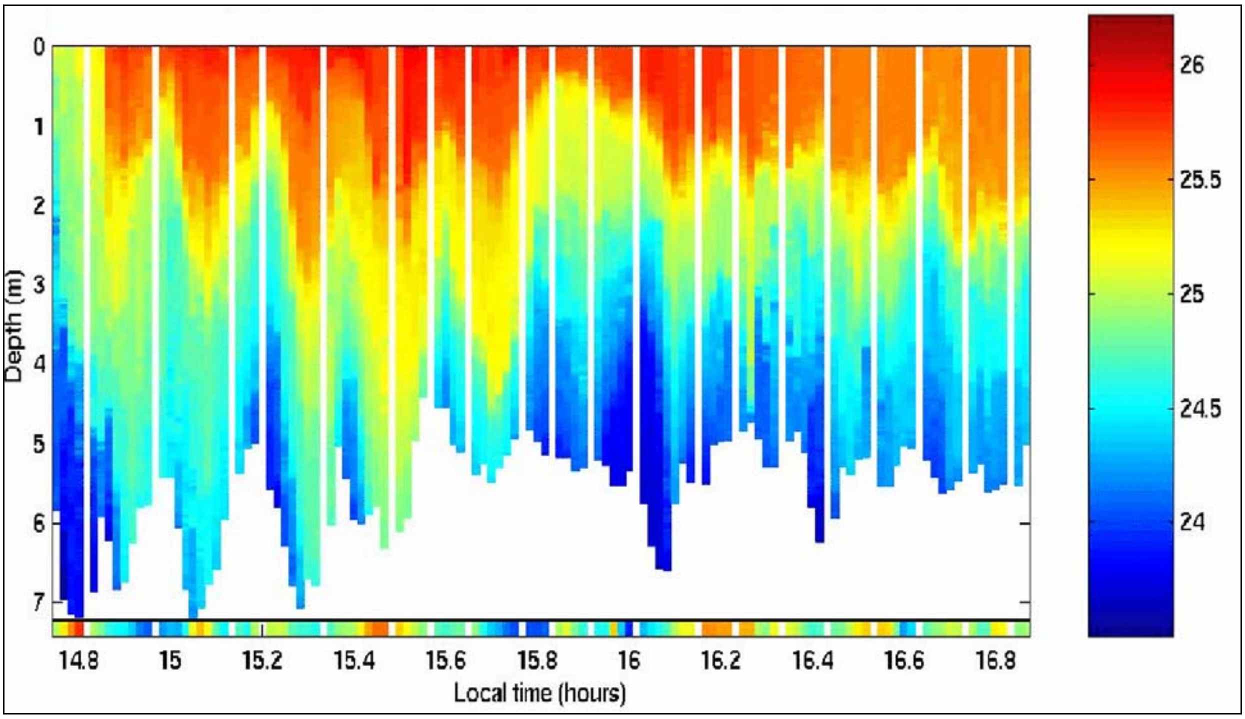


Figure 6.3.1. Time evolution of near-surface thermal gradients SkinDeEP profiles on 12 October 1999. Off Baja California, R/V Melville. From Ward, B. and P. J. Minnett, 2001. An autonomous profiler for near surface temperature measurements. Gas Transfer at Water Surfaces. M. A. Donelan, W.M. Drennan, E.S. Saltzmann and R. Wanninkhof (Eds.) American Geophysical Union Monograph 127. 167 - 172.

Minnett then explained the fundamental principles of a Fourier Transform Interferometer, which is the heart of the M-AERI system, used by the University of Miami RSMAS to collect in situ spectra of the sea surface for validation of SST. Minnett noted that the M-EARI instruments had all been calibrated using NIST traceable blackbody systems, checked by NIST radiometers during the last Infrared radiometer inter-calibration workshop completed recently. Data have been collected during several cruises in most oceans during the 1996-2002 period that have been used to validate satellite SST observations. However, an operational deployment has been set up aboard The *Explorer of the Seas*, a Royal Caribbean Cruise Liner, operating a bi-weekly schedule out of Miami. It is outfitted as an oceanographic and atmospheric research vessel, very suitable for satellite validation. For more details see http://www.rsmas.miami.edu/rccl/ Figure 6.3.2 shows an overview of the Explorer of the Seas, the installation of the M-AERI instrument and the track taken by the ship during normal operations. Figure 6.3.3 shows a time series of MAERI data collected aboard the Explorer of the seas in 2001. Over 29000 SSTskin measurements were obtained during a 12 month period. Also plotted in this figure is the SST at depth (red line). Significant diurnal and seasonal signals are clearly seen in this plot highlighting the variable nature of SST in the region.

Figure 6.3.2. Operation of M-AERI aboard the The Explorer of the Seas (top Left). Top right panel: installation of the M-AERI. Bottom panels: cruise tracks of the ship.

Minnett then presented data collected during a research cruise aboard the R./V Mellville to investigate the character of the SSTskin–SSTdepth relationship to the surface wind speed and solar flux which is shown in Figure 6.3.4 below. In this plot, data have been coloured according to the time of day (local time) that they were observed. Clearly seen in this figure is are the strong warm deviations during the daytime and cool skin deviations at night when the wind speed is low. Considerable diurnal deviations of up to 4K are evident from this figure when the wind speed is low highlighting the need for the GHRSST-PP community to account for diurnal signals prior to merging and analysis of satellite data. To highlight this issue the overpass times of the TERRA and AQUA satellites has been marked onto this figure. The morning and afternoon overpasses straddle the time of local SST diurnal maximum.

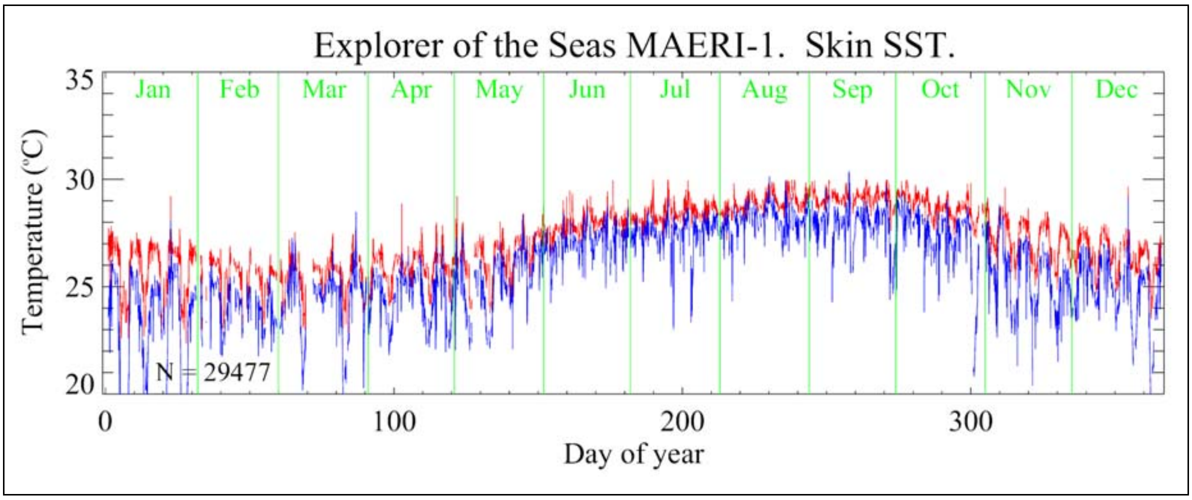


Figure 6.3.3. Time series of SSTskin (blue line) and SST7m (red line) in the Caribbean obtained form the Explorer of the Seas in 2001. (P. Minnett).

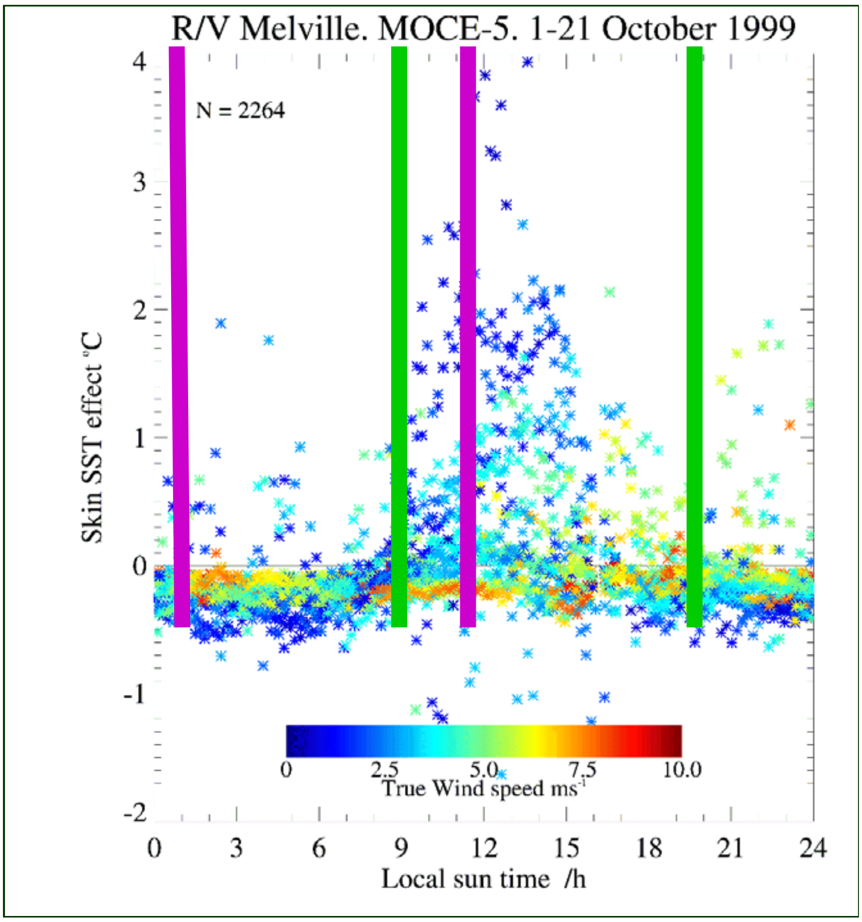


Figure 6.3.4 Wind speed dependence of the sSSTskin-SST7m highlighting diurnal and skin effects. TERRA and AQUA overpass times are marked as vertical magenta and green lines respectively. (P. Minnett)

ME-AERI data has been used to validate Pathfinder SST for several cruise data sets shown in Figure 6.3.5. Table 6.3.1 shows the mean results obtained from the validation study for each of the separate cruise data sets and the mean total. It is clear from this table that the use of SSTskin as opposed to SSTdepth measurements reduces uncertainties by approximately a factor of two. Furthermore, the mean validation result reveals practically zero bias highlighting the quality of the Pathfinder SST data set. This is an odd result as the

Pathfinder SST retrieval a algorithm is tuned to SSTdepth so that in a validation using SSTskin, one might expect a warm bias of ~0.2-0.4 K. Minnett suggested that the day/night differences between the validation data are effectively cancelling warm and cool biases associated with day/night conditions. It was also noted that the number of measurements was several orders of magnitude greater than the final number of validation match-ups (254) which is a reminder of how difficult it is to obtain in situ SSTskin measurements for satellite validation.

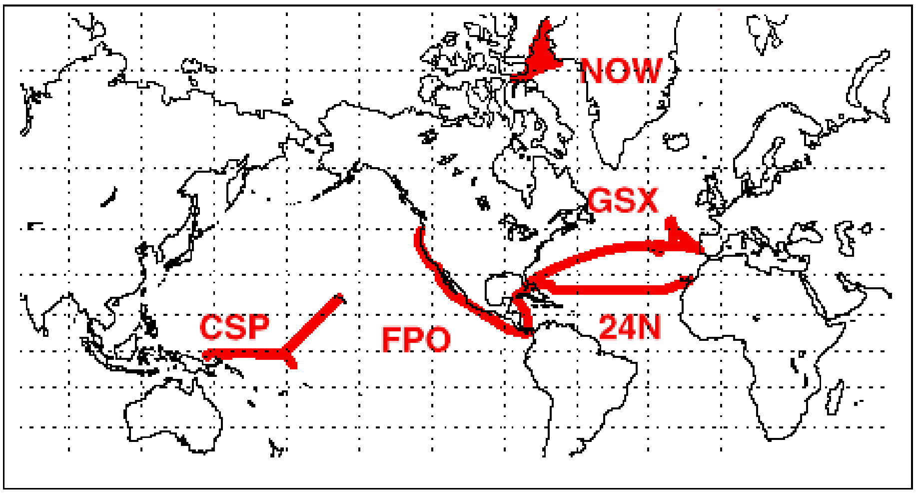


Figure 6.3.5 Location of cruise data sets used to validate AVHRR Pathfinder SST data products summarised in Table 6.3.1. (P. Minnett)

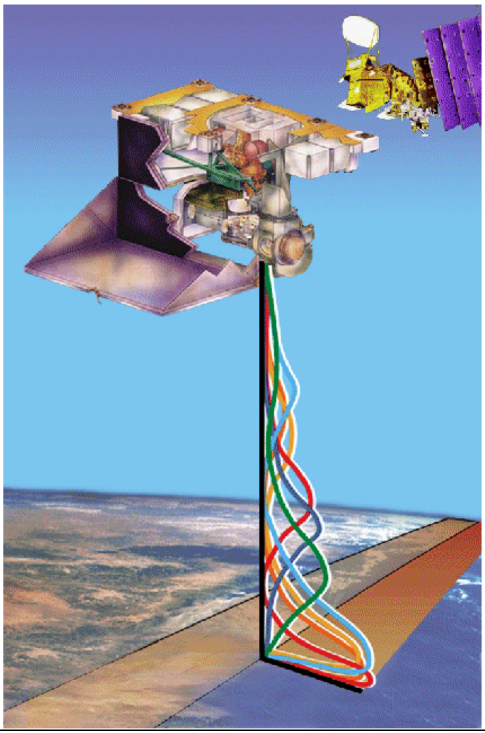
Minnet concluded by noting that Using skin SSTs to validate satellite-derived SSTs gives a better estimate of uncertainties in the satellite-derived fields. M-AERI and other radiometers are capable of meeting validation requirements but ut remains that a significant number of deployments are required to generate a data set of significant numbers. Even then, separating instrumental effects from environmental effects is a significant challenge. Data show that the thermal skin effect is much less variable than previously thought, and relationship at night or in moderate to high winds is good (e.g., Donlon et al, 2002). Finally the implications of diurnal variability remains a significant challenge to GHRSST-PP.

Table 6.3.1 Validation statistics for Pathfinder SST using in situ observations collected along the cruise tracks shown in Figure 6.3.5. (P. Minnett)

Cruise Name	N	Mean K	St. Dev. K
CSP 1996	23	0.16	0.20
24N 1998	16	0.03	0.18
GASEX 1998	168	-0.01	0.25
FPO 1998	47	0.27	0.40
NOW 1998 (Arctic)	176	0.24	0.44
Total, all data	430	0.13	0.37
Total, excluding NOW data	254	0.06	0.29

6.4 P. Minnett, AIRS: the Atmospheric Infrared Sounder

Minnet then continued with a brief introduction to the AIRS instrument that is flown on the Aqua satellite together with AMSR-E and MODIS (13:30 ascending node).. The AIRS instrument is a grating spectrometer that has been well characterized prior to launch. The AIRS web page can be found at http://www.jpl.nasa.gov/airs. Figure 6.4.1 provides a schematic of the AIRS instrument in flight together with a technical summary of the main characteristics of the system.



Mission:
Earth Observing System (EOS)
NASA Polar Platform 2 (Aqua)

Science Objective:
Determine Global Atmospheric Temperature and Humidity Profiles

Technique:
Multispectral IR Remote Sensing

• Vertical Coverage	0-25 km
• Vertical Resolution	1 km
• Temperature/Humidity Accuracy:	1 K/10%
• Ground Footprint:	13 km x 13 km @ Nadir

Instrument:
Array Grating Spectrometer

• IR Spectral Coverage	3.74-4.61 µm 6.20-8.22 µm 8.80-15.4 µm
• IR Spectral Resolution, $\lambda/\Delta\lambda$:	1200
• IR Spectral Samples:	2378
• Sensitivity (NEΔT):	0.2 K
• 4 Visible Channels:	0.4-1.0 µm
• Operating Lifetime:	5 years

Figure 6.4. 1 The main characteristics of the AIRS instrument.

Minnett noted that while the AIRS instrument has a large spatial footprint (13 km) it has the capability of providing an exceptionally accurate SST measurement by taking advantage of micro-atmospheric windows between spectral lines. The cleanest lies at 2616 cm-1 (3.823µm). The AIRS team plan to cloud screen using spatial coherence techniques over 9 pixels (each ~15km diameter), and additionally using the signal within a weak water vapour line. Clear sky pixels ~1% return rate (c.f. 8-12% for 4km AVHRR Pathfinder; Kilpatrick et al, 2001) ~20,000 clear ocean pixels/day.

However, if the atmosphere is clear for AIRS then it is also clear for other IR sensors that have a higher spatial resolution. The strength of the AIRS SST lies in the fact that it can provide an independent SST retrieval, based on a different type of atmospheric correction. Finally, Minnett concluded that the AIRS instrument should be included in the GHRSST-PP and that there was already some interest from the AIRS team for this purpose.

6.5 I. Barton, Pearce and Mahoney: Validation of AATSR SST in Australian Waters

No abstract available.

6.6 R. Evans: A comparison of MODIS AQUA and TERRA SST using MAERI and buoy observations

Bob Evans presented an overview of the MODIS instrument noting that the major strength of MODIS is that it has a good accuracy and provides global coverage in a single day. There are 86 ocean parameters available in over 100 categories of MODIS Ocean data types archived by (and may be obtained from) the NASA Goddard Distributed Active Archive Center. There are three basic groupings of MODIS ocean data parameters are:

- ocean color
- sea surface temperature
- ocean primary production

Considering all of the ocean parameter categories the number of data products breaks down to:

- 36 Ocean Color parameters
- 4 Sea Surface Temperature parameters
- Primary Productivity parameters
- (including 2 Primary Production indices)
- 38 Quality Control parameters.

Ocean color and sea surface temperature are available at a variety of processing levels. Level 1 data products represent unprocessed top of the atmosphere radiance/reflectance at 1-km spatial resolution and on 5 minute granule time resolution. Level 2 data are swath data at 1-km spatial resolution (approximately 2000 x 2000km) and 5 minute granule time resolution. Level 3 data represent global binned or mapped data having spatial resolutions of 4.63km, 36km, or 1 degree (binned) and time resolutions of one day, 8 days, a month or a year. Binned data products use an integerized sinusoidal equal area grid (ISEAG) whereas the mapped products use a Cylindrical Equidistant Projection.

Evans then explained that the MODIS team operate a quality control system called MQABI that can be accessed via the MODIS Quality Assurance Web Page http://jeager.gsfc.nasa.gov/browsetool/. The web page provides access to the available MODIS Ocean data collections, the ability to browse selected fields and links to information concerning the status of the Ocean products.

MODIS SST data are validated using in situ observations and are classed as either 'Validated' andf the products have a known error level or as 'beta' data products indicating only a provisional validation has been achieved. The current validation status of TERRA and AQUA SST data products is

- TERRA (beta->valid) mid-wave 4µm SST (SST4)
- TERRA (valid->improved valid) thermal 10-11µm SST
- AQUA (beta->valid) mid-wave 4µm SST (SST4)
- AQUA (beta->valid) thermal 10-11µm SST

These validated products will be delivered to the DAAC when product production based on the latest code delivery commences. Table 6.6.1 presents an overview of the validation statistics for MODIS SST data obtained using drifting buoys and M-AERI observations.

Table 6.6.1 MODIS SST Buoy and M-AERI retrieval Statistics Version 4.5 (new delivery).

MODIS SST Buoy and M-AERI retrieval Statistics
Version 4.5 (new delivery)

median = satellite - reference [MAERI or BUOY]

BUOY

- **SST - new coefficients**

	Median	StdDev	Number of Points
– Terra all	-0.07	0.48	11027
– Terra night	0.01	0.42	4387
– Terra day	-0.14	0.51	6643
– Aqua all	-0.05	0.48	3821
– Aqua night	-0.10	0.43	1628
– Aqua day	-0.01	0.51	2203

- **SST4 new coeffs, new formulation**

	Median	StdDev	Number of Points
– Terra night	-0.05	0.41	4096
– Aqua night	-0.10	0.39	1319

SST pixel-pixel sst noise < 0.03K
SST detector-detector noise ~ 0.06K

M-AERI

- **SST - new coefficients**

	Median	StdDev	Number of Points
–Terra all	0.10	0.40	439
–Terra night	0.04	0.35	235
–Terra day	0.16	0.42	204
–Aqua all	0.06	0.40	105
–Aqua night	0.02	0.37	59
–Aqua day	0.11	0.45	46

- **SST4 new coeffs, new formulation**

	Median	StdDev	Number of Points
–Terra night	0.02	0.34	278
–Aqua night	-0.01	0.31	52

Evans noted that both TERRA and AQUA SST and SST4 products show no trends with time (Jan 01-Sept 02), temperature, satellite zenith angle (not shown) or latitude *vs* drifting buoys with over 50% of the retrievals lying within a +/- 0.2K error band. This is an extremely encouraging result.

Evans explained that the MODIS team is providing active support of other EOS instruments. For example a special 0.25O spatial resolution AQUA SST has been delivered to AMSR and AIRS teams to assist in product assessment and validation. Active support for international SST projects is an on-going theme of the group and M-AERI in situ time series has been provided to ENVISAT AATSR team for product validation. Finally, the group is working with the GODAE Global High Resolution SST (GHRSST) team to integrate MODIS SST products into the international effort to define and deliver a validated global, near real-time high resolution SST product.

Evans concluded with a summary of on-going activities within the MODIS team. These include:

- Improve data quality tests to better identify suspect or invalid SST retrievals
- Add to M-AERI match up data base to include all M-AERI cruises for better quantification of SST retrieval statistics
- Extend the buoy match-up to include all of the TERRA mission
- Continue to work with microwave products to first identify and subsequently correct for the presence of aerosols
- Top work with EOS and international teams to improve SST validation, exchange M-AERI match-up observations and TERRA/AQUA SST and SST4 global fields
- To work with GODAE Global High Resolution SST working group to better define estimation of diurnal thermocline leading to a proper merger of AQUA and TERRA day and night SST fields

6.7 Lisa Horrocks, Jim Watts, Roger Saunders and Anne O'Carroll: Validation of ENVISAT AATSR data at the UK Met. Office (presented by A. Hines)

Adiran Hines presented the AATSR validation work of L Horrocks et al. that had been conducted at the Met Office, UK. An extensive data processing system has been designed and installed at the Met Office for the AATSR validation effort that has built on the experience gained during the AATS/1 & 2 validation campaigns. Figure 6.7.1 provides a schematic overview of the processing system.

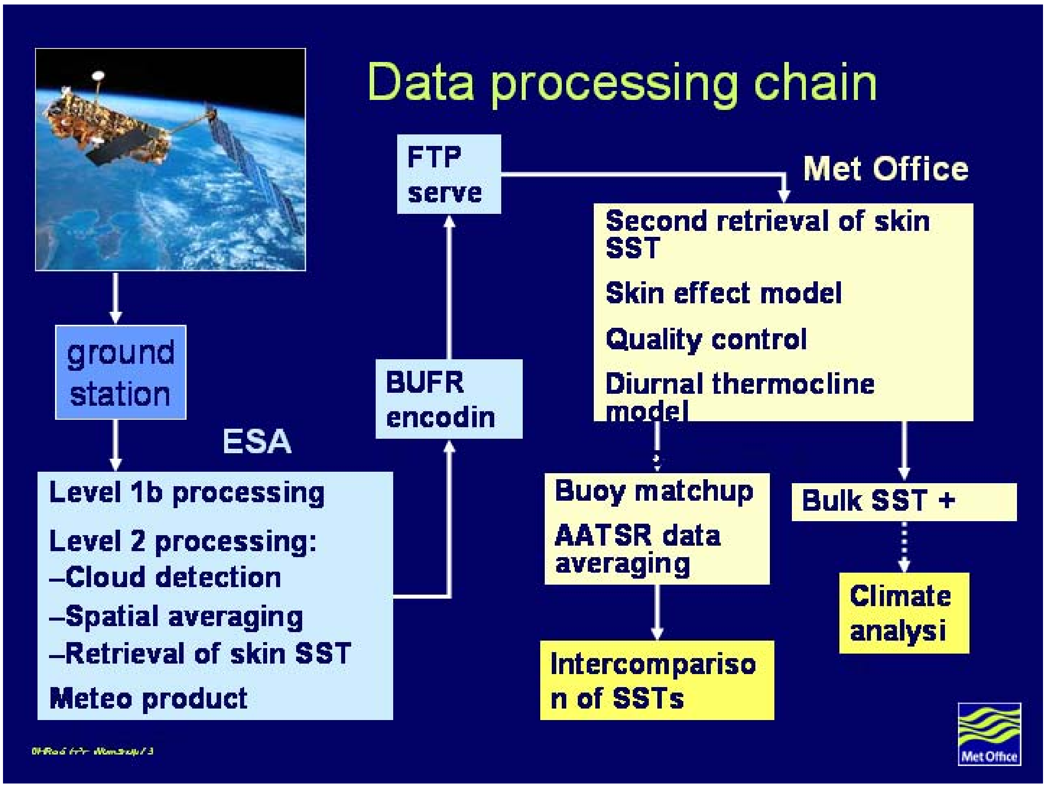


Figure 6.7.1 Data processing system at the Met Office UK for the validation of ENVISATR AATSR data. (L. Horrocks).

The Met Office receives AATSR Meteo data products in BUFR format via direct ftp pull from ESA servers in near real time. The AATSR Meteo product arrives as orbit files and includes clear sky spatially averaged (10 arc minute resolution) SST measurements. Both a dual-view and single-view SST retrievals (SKIN) are provided. In addition, brightness temperatures (3.7, 11, 12um) data are provided in two views. Confidence information is also provided with each brightness temperature and SST measurement for quality control purposes. The near-real time service from 19 August 2002.

At the Met Office, a second retrieval of SSTskin is made, a skin effect model and diurnal warming model is run and extensive QC is performed. AATSR data are then matched to buoy observations and real time inter-comparisons are computed and published via a password protected web interface. In addition, an SSTdepth algorithm is applied to the AATSR data to retrieve an estimate of the SST1m for climate analysis.

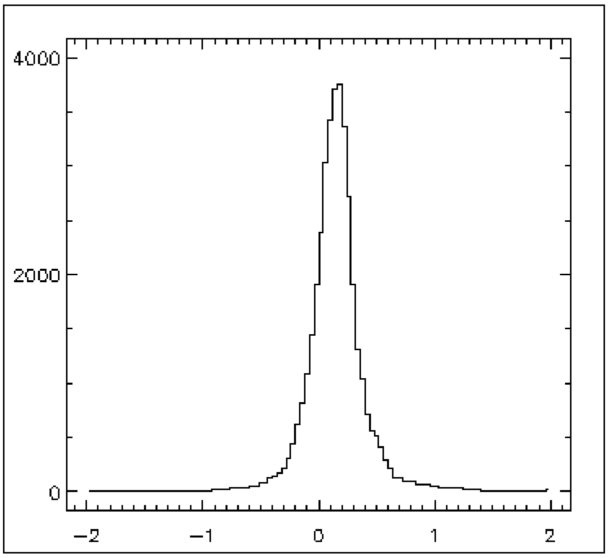
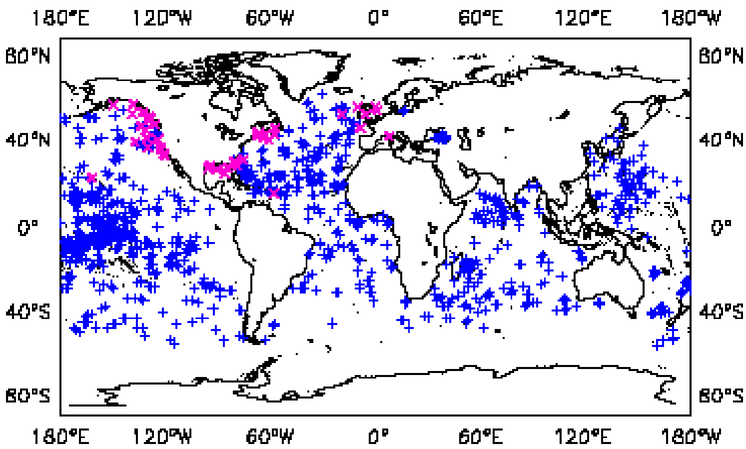
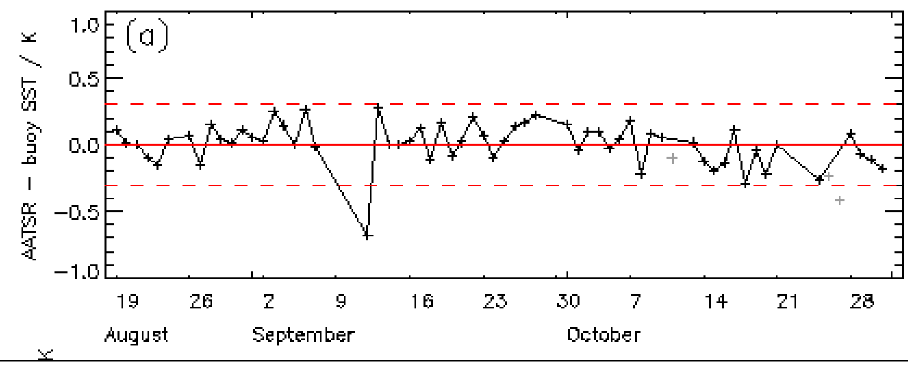


Figure 6.7.2 Comparison between AATSR dual-3 minus dual-2 SST data. (L. Horrocks, Crown copyright)

Figure 6.7.2 shows a comparison of the AATSR dual 2 channel and dual 3 channel SST algorithm obtained on October 20th 2002. Only night time data have been used in this figure that shows the dual-2 channel SSTs are ~0.2K cooler than dual-3 channel SSTs. This is a similar magnitude discrepancy to that seen with ATSR-2. this result has implications for day-night biases in Meteo SST suggesting that adjustments are required to the retrieval.



(a)



(b)

Figure 6.7.3 AATSR Meteo SST - buoy SST for the period August – October 2003. (a) location of match-up data (b) Time series of Meteo SST – buoy SST. (L. Horrocks, Crown copyright)

Validation of AATSR has been performed using quality controlled buoy data. Several tests are used to screed erroneous data from the analysis including a weekly buoy - NWP background test and a gross check of each reported SST against climatology. The match-up criteria used in the analysis are such that buoy and AATSR data must be collocated to within 10 arc minutes and coincident within ± 3 hours. Figure 6.7.3 shows the results obtained so far for the period August – October 2002.

For a comparison of ~1500 match-up data points, Means over the period 19 Aug - 31 Oct the mean difference between buoy and AATSR for all data is 0.02 K(s.d. 0.55 K). If only night time data are considered, a bias of = 0.02 K(s.d. 0.44 K) is found. The anomalous data seen in figure 6.7.3 on the 12 September is for two match-ups located off San Francisco where AATSR ~4 K colder than the buoy observation. It is thought that this is due to undetected stratocumulus cloud.

Figure 6.7.4 shows the difference between AATSR SST and buoy SST as a function of wind speed for the period 19 Aug to 31 Oct 2002. 572 night time match-ups are used in this figure. Surprisingly, the AATST match-up data do not conform to the expected negative delta T values when compared to the Fairall skin effect model forced with NWP model flux and wind data suggesting that AATSR data are slightly too warm. Several published models have been tested against ship data and the Fairall (1996) model performed particularly well for ATSR-2/buoy match-ups. This model is used to apply a conversion factor to produce a "bulk" SST from the AATSR SSTskin data

AATSR monthly SST data have been compared to the Hadley Centre climatological SST data set (HadSST) for September and October 2002. considering global averaged data, the AATSR is shown to be ~ 0.075K (0.78K rms) cooler than HadSST. When the AATSR Met Office 'bulk SST' product is compared to HadSST, a warm bias of ~0.07K (rms of 0.78K) is found. The largest differences are found in cloudy areas, close to ice-edge and in areas of strong SST gradients as expected. Regional statistics are also computed but there is not yet enough data to detect any significant patterns.

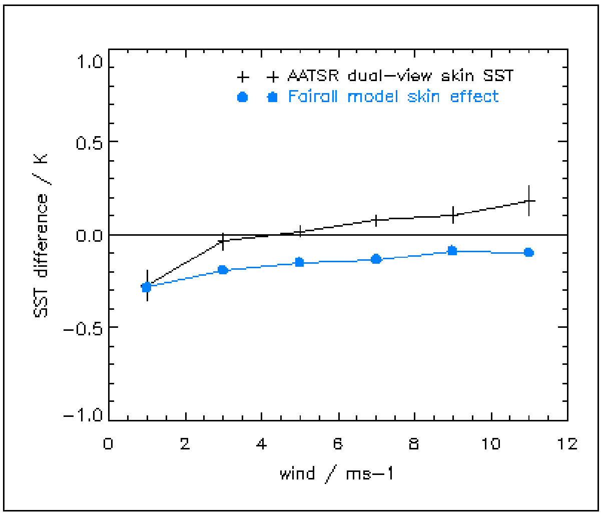


Figure 6.7.4 Black line shows the difference between AATSR SST and buoy SST as a function of wind speed for the period 19 Aug to 31 Oct 2002. Blue line shows the computed data for the Fairall skin effect model forced with NWP model flux data and wind speed data. (L. Horrocks, Crown copyright)

Some experiments have been performed to detect diurnal warming events using the Kathna and Clayson ocean model (1994). The model is forced by NWP model flux and wind data and run from local dawn to the AATSR observation time for daytime data only.

The results f this procedure are used to flag observations and inflate associated error rather than as conversion factor. Initial results show that there are not many incidents > 0.2 K. This may be due to the accuracy of fluxes or in the model itself.

In conclusion, the AATSR product validates well against buoys and climate data: SSTs within expectations. Inter-algorithm differences ~0.2 K (as ATSR-2) are present and there is evidence of undetected cloud in difficult areas. Retrieved AATSR SSTs might be slightly warm (< 0.3 K). The validation work at the Met Office will continue as a routine monitoring procedure. Finally, comparisons with ship and AATSR data show that the cool skin effect can be well-modelled using the Fairall et al. scheme.

6.8 A. Jessup: Long-term Measurements of Skin and Near-Surface Temperature on the R/V Brown

No Abstract available.

7 Session 5: GHRSST-PP R&D methods December 4th

This session, chaired by Gary Wick and Andy Harris, provided a review of several key research developments that are relevant to the GHRSST-PP.

7.1 R. W. Reynolds: OOPC SST Working Group and Buoy Need Requirements

Richard Reynolds began by reminding the workshop that Sea Surface Temperature (SST) and Sea Ice Working Group (WG) (that report to Reports to GCOS AOPC and OOPC Panels) should have strong links to the GHRSST-PP. This is indeed the case as Nick Rayner chairs the Sea Ice group and Richard Reynolds chairs the SST group. For both of these groups the focus is on Climate aspects. The Terms of Reference are:

- Record and evaluate the differences among historical and near-real-time analyses
- Identify the sources of these differences
- Establish criteria to be satisfied by analyses to ensure the quality and consistency
- Recommend actions needed
- Report annually

Specific tasks assigned to these groups include:

- investigating the quality control (QC) and analysis procedures to determine why the SST analyses differ.
- Examination of the accuracy of sea ice fields and sea ice to SST conversion algorithms.
- Determine the impact of the SSTs from temperature profile data (XBT, Argo, etc.) on SST analyses
- Develop an interface between SST data users and SST data providers to indicate where future buoy deployments are needed
- A specific task is to maintain a link between the GODAE High-Resolution SST project and the SST and sea ice working groups.

As such the results of the GHRSST-PP workshop will be reported back to the SST and sea ice groups.

Reynolds then focussed on the buoys need for Sea Surface Temperature (SST). The purpose of this work is to objectively determine where new drifting buoy (or other equivalent in situ) data are needed. There are two data requirements for in situ SSTs:

1. In situ data are needed to bias correct satellite retrievals
2. In situ data are needed to analyze SSTs in regions without adequate satellite and/or in situ data.

Reynolds noted that a higher density of in situ data are needed to supplement other data than for bias correction requirement. The focus of this work was on seasonal time scales. The basic methodology used weekly NOAA Optimum Interpolation (OI) SST Analysis as a metric to determine a "Buoy Need". Weekly data were combined in order to obtain seasonal requirements. Weekly data were then combined to estimate seasonal requirements by adding synthetic buoy data to the analysis. In this method there are two analysis steps and 2 Buoy needs (1) in a satellite data bias correction procedure and (2) in the OI analysis itself.

For an acceptable bias correction, 1 buoy observation or 6 ship observations are required on a 12° grid for at least 75% of weeks in a season. 6 ship observations roughly equal to 1 buoy observation where the buoy error used in the OI is 0.5°C and the ship error used in OI is 1.3°C. If one assumes ship error is random, then the number, *n*, of ship observations to reduce ship error to 0.5°C is ~6.

The OI normalized error is a factor which reduces the error of the initial first guess error. Typically, the range of the OI normalized error is 0 for perfect data and 1for no data. The OI normalized error correctly weights data with different expected errors e.g., higher error for ships & lower error for buoys. It is function of the assumed OI error statistics and independent of SSTs values. Figure 7.1.1 shows the computed normalized OI error for in situ observations between January 2 - 8 2002. Clear correlations between the coverage of in situ data and the Normalized OI error are visible.

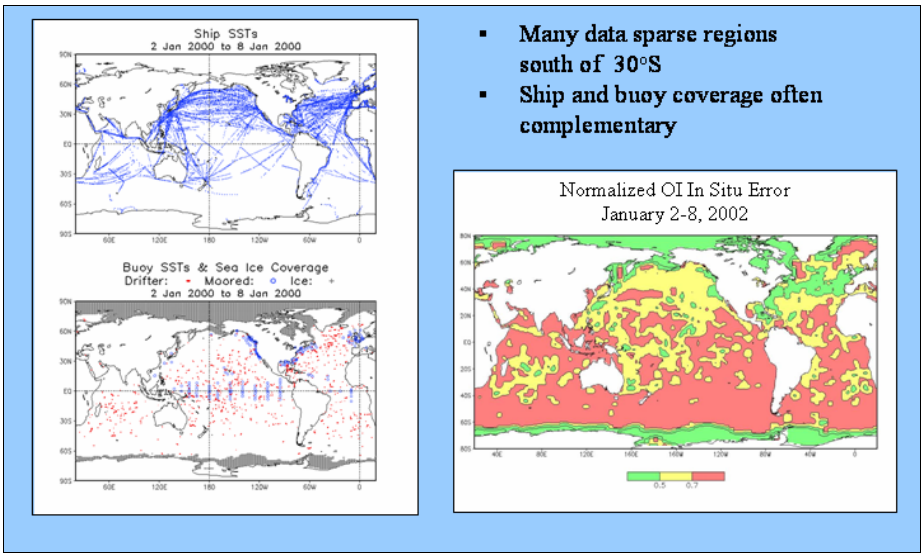


Figure 7.1.1. The Normalized OI error for in situ SST coverage. (R. Reynolds).

Figure 7.1.2 shows the same analysis but for satellite SST data rather than for in situ buoy data. Immediately obvious is the effect of considerably increased data coverage when compared to the in situ case reducing the Normalized OI error to ~0.5 in most areas with notable exceptions where satellite data are sparse.

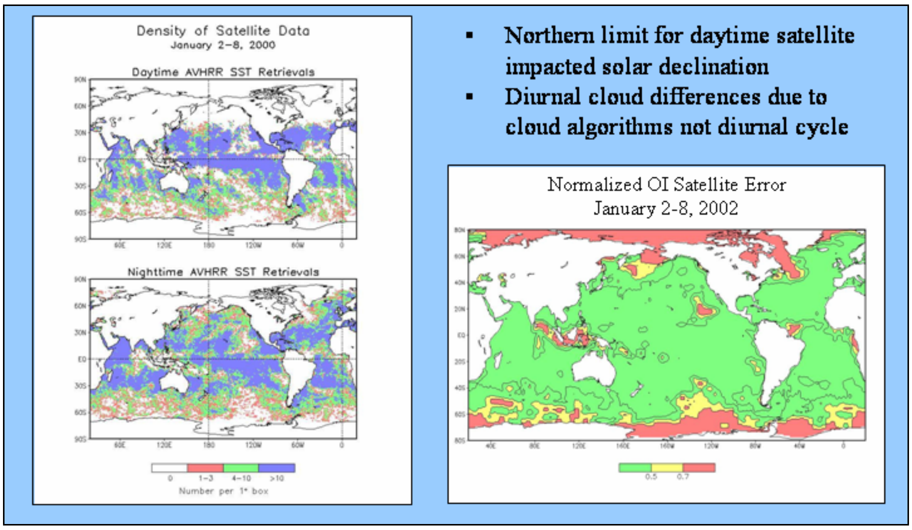


Figure 7.1.2. The Normalized OI error for satellite SST coverage. (R. Reynolds).

Based on the combined in situ and satellite normalized OI error (Figure 7.1.3), the following error criteria were set:

Coverage	**Definition**
Good	E **<** 0.5
Fair	0.5 **<** E **<** 0.7
Poor	E **>** 0.7

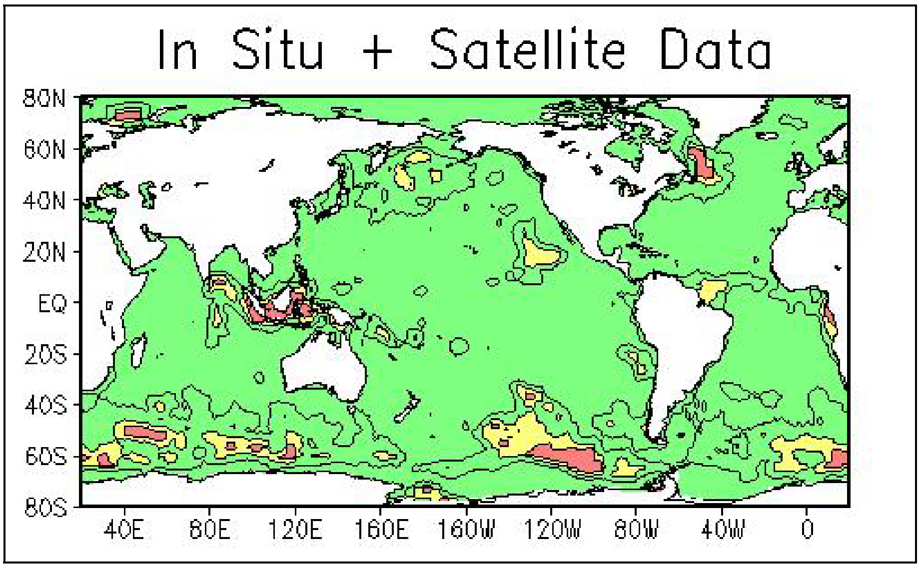


Figure 7.1.3 Combined in situ and satellite normalized OI error. Green < 0.5, yellow 0.5 – 0.7 and red > 0.7(R. Reynolds).

The Seasonal Average Normalized OI Error for In Situ and Satellite data was then investigated assuming that the desired maximum Normalized OI Error level is 0.5. In locations where the error > 0.5, simulated buoys were added on a 4° grid and the OI Error is recomputed. If the new error > 0.5, additional simulated buoys are added on a 2° grid until the error falls below 0.5. Figure 7.1.4 shows the results if this analysis for a 1/12° grid and Figure 7.1.5 shows the result of the analysis for four seasons over 2001-2002

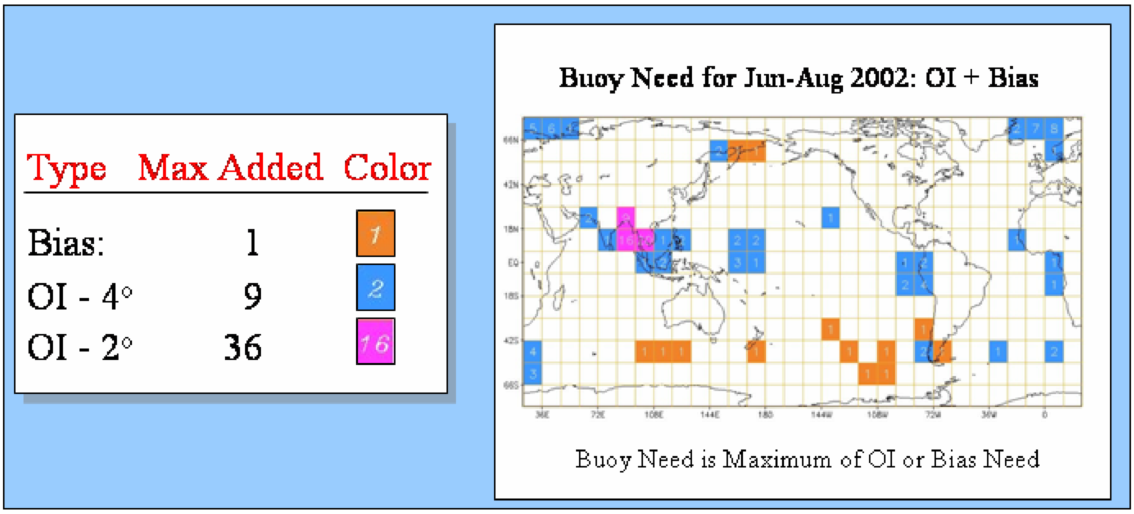


Figure 7.1.4. Buoy Need for Jun-Aug 2002 (OI + Bias), (R. Reynolds)

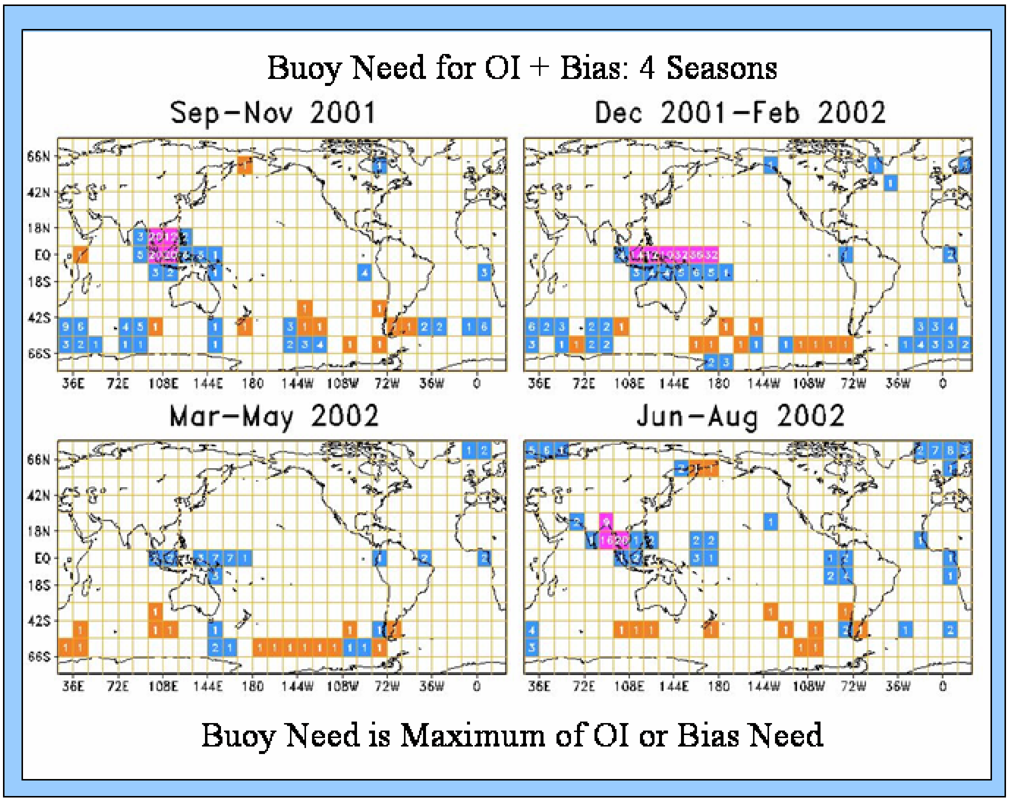


Figure 7.1.5. Buoy Need for four seasons (OI + Bias). Colors same as for Figure 7.1.4 (R. Reynolds)

A set of maps are now planned for each current season plus the 4 preceding seasons so that changes in Buoy Need are apparent. It is not expected that high buoy needs (e.g., > 9 per 12° grid box) will be met by deployment unless these grid points are in open ocean regions, persist over several seasons and persist for the same season for several years.

Reynolds noted that the buoy needs from Bias Correction & OI Error are defined by subjective criteria such that buoys are added to assure 1 buoy (or equivalent) on a 12° grid and to keep the Normalized OI Error < 0.5. These criteria are arbitrary and can be adjusted to make the deployments practical. In addition, deployments can be limited in special regions such as high latitudes and coastal regions. Furthermore, simulated buoys do not drift in terms of their error. OI error weights for drifting and moored buoys are the same (0.5°C). also, the OI is done on a 1° grid and drifting buoys may cover several grid points during a week so that drifting buoys may have larger impact. In order to account for this, the next version of Buoy Need will use NCEP Ocean Model velocity climatology to allow drifters to advect with surface currents.

The results discussed above are a nowcast but seasonal changes will impact the outcome. Ships tracks change seasonally due to avoidance of storms but also and cloud cover and the solar declension changes with season and impacts satellite data. In order to address these issues, once the advection component is added, Buoy Need will be adjusted for climatology to give a better Forecast for the new season. The number of in situ and satellite observations will be increased or decreased by expected seasonal changes and seasonal NCEP velocities for each new season will be used. However, the most important requirement for the Buoy Need maps is to investigate the use of Microwave data in both the OI and Buoy Need. This work is currently in progress.

7.2 J. Vasquez et al.: The Effect of Aerosols and Clouds on the retrieval of SST from AVHRR and ATSR2

A comparison study was undertaken to examine the sea surface temperatures as derived from the Along-Track Scanning Radiometer (ATSR) on board the European Remote Sensing Satellite (ERS-2) (ASST2) and the NOAA/NASA AVHRR Oceans Pathfinder data set, which uses the modified pathfinder sea surface temperature algorithm (MPFSST). Difference maps are created between the MPFSST and the ASST2 defined by MPFSST-ASST2. These differences maps are used to examine the significance of aerosols and/or cloud contamination on the MPFSST and the ASST2.

A simple statistical model, using cloud and aerosol data from the Total Ozone Mapping Spectrometer (TOMS), is applied to the MPFSST and the ASST2. A regression, based on the ASST2, MPFSST versus the cloud and aerosol TOMS data, is used to remove the part of the MPFSST and the ASST2 that can be explained, in a linear fit, by the aerosol and cloud data. Results (see Figure 7.2.1) indicate that after application of the linear correction, global mean differences were reduced to approximately +0.1°C ± 0.4 for the daytime and –0.1°C ± 0.3 for the nighttime results. However these results varied regionally with the largest improvement in areas off the coast of Western Africa, where aerosols are known to be problematic.

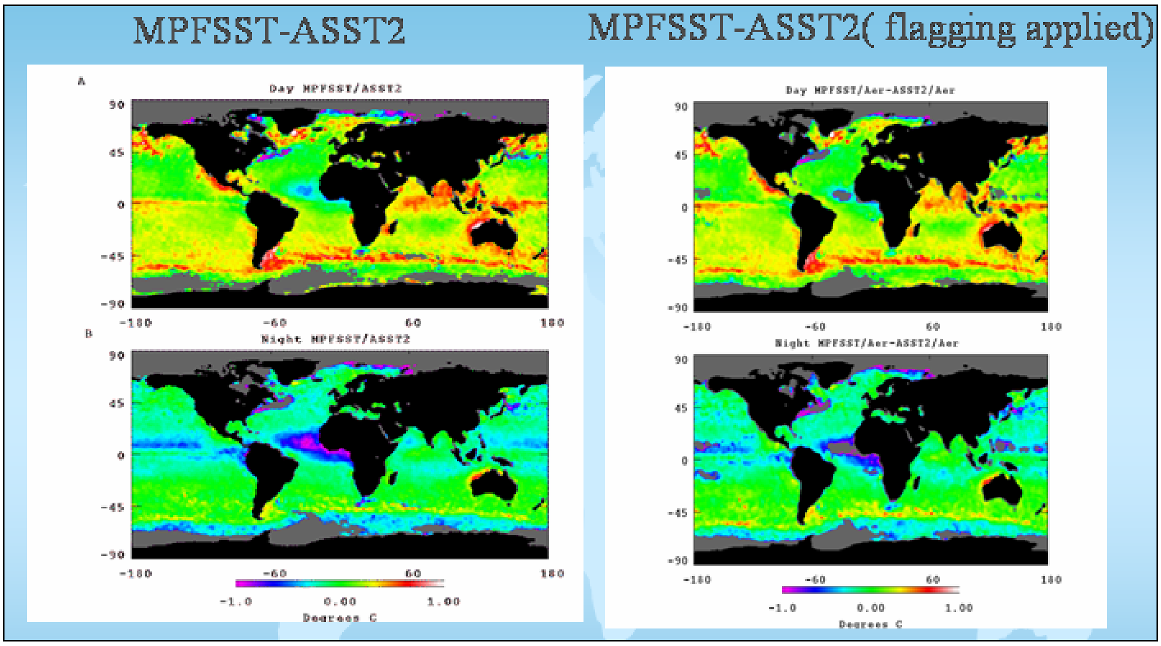


Figure 7.2.1 Left: Pathfinder SST – ATSR2 ASST top panel daytime and bottom panel night-time. Right column: Same as left column except with linear aerosol flagging correction applied. (J. Vasquez)

Additionally mean differences were reduced in areas of known cloud contamination, such as the North Atlantic. Considering that the MPFSST measures a SST tuned towards a bulk temperature and the ASST2 measures a skin temperature future studies should concentrate on whether remaining differences can be attributed to skin-bulk and/or diurnal differences.

7.3 C. Mutlow: the ATSR Programme – a reference SST data Source?

Chris Mutlow discussed the need for a reference SST data set. Stability of data is a critical issue demanding careful sensor design to minimise short-term orbital variations and to provide long-term stable operations. There is a need for careful pre-flight characterisation of sensors to minimise need for empirical post-launch corrections. A stable sun-synchronous orbit removes need of time of day corrections from drifting orbits. Perhaps most importantly, a good calibration system, traceable to international standards (e.g., ITS90 or radiometric standard) is required for both pre- and in-flight operations. The system should have robustness to the atmosphere and its changes. For a long term reference data set requiring several follow on sensors, an overlap of missions is required to allow direct inter-comparison of successive sensors and to avoid unexpected "jumps" in data. Finally, the long-term continuity of data must also be considered.

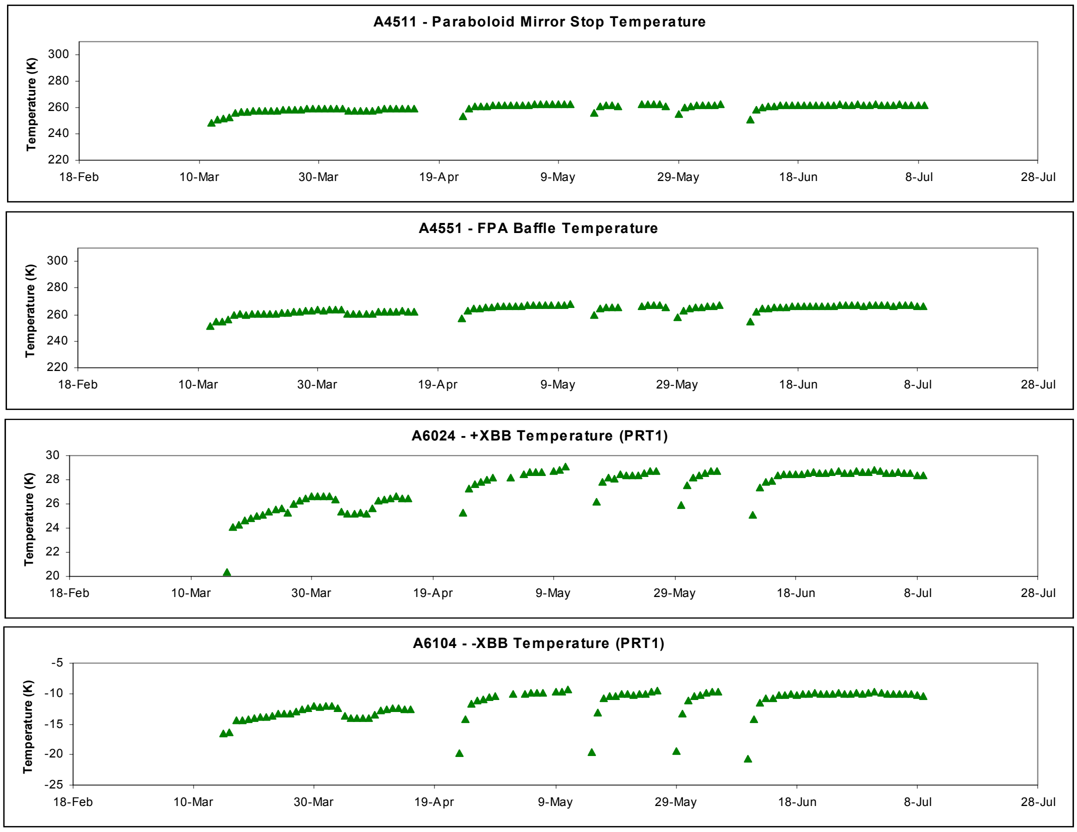


Figure 7.3.1. Stability of the ATSR parabolic mirror stop, FPA baffle and blackbody temperatures. (C. Mutlow)

Mutlow then noted that the Along Track Scanning Radiometers (ATSR) instruments, a series of imaging radiometers designed specifically for the purpose of climate change detection. Currently the Advanced ATSR (AATSR), ATSR/1 and ATSR/2 are flying with the ATSR/1 in a parked orbit. Together, this series of instruments will provide 15 years of continuous data. All three ATSRs have spectral channels centred at 1.6, 3.7, 10.8 and 11µm. In addition ATSR-2 and AATSR have visible channels centred at 0.55, 0.67 and 0.87 µm. The innovative design of these instruments addresses many of the issues required for a reference data set.

Mutlow noted that the ATSR series provides exceptionally stable data due to the sensor design which minimises short-term orbital variations and maximises long-term stable operations. Examples of various engineering parameters (mirror and focal plan array temperatures, detector Stirling cycle cooler) were presented that demonstrate the stability of the ATSR (see Figure 7.3.1).

The AATSR uses a stable sun-synchronous orbit which almost removes need of time of day corrections from drifting orbits. Careful pre-flight characterisation of AATSR sensors has been performed using a dedicated space test facility specially constructed for the ATSR instruments (see Figure 7.3.2). This system has removed need for empirical post-launch corrections. The ATSR on-board calibration system provides exceptionally good calibration.

It is traceable to ITS90 international standards with both pre- and in-flight calibration traceable to NPL and NIST. In addition, the ground calibration system preserved in clean environment.

Due to the innovative along track scanning geometry of the AATSR sensor, there is an inherent robustness to atmospheric attenuation and changes in atmospheric structure. There is an overlap of data between the ATSR missions with over 1 year for ATSR-1 and 2 and over 6 months for the AATSR and ATSR-2.

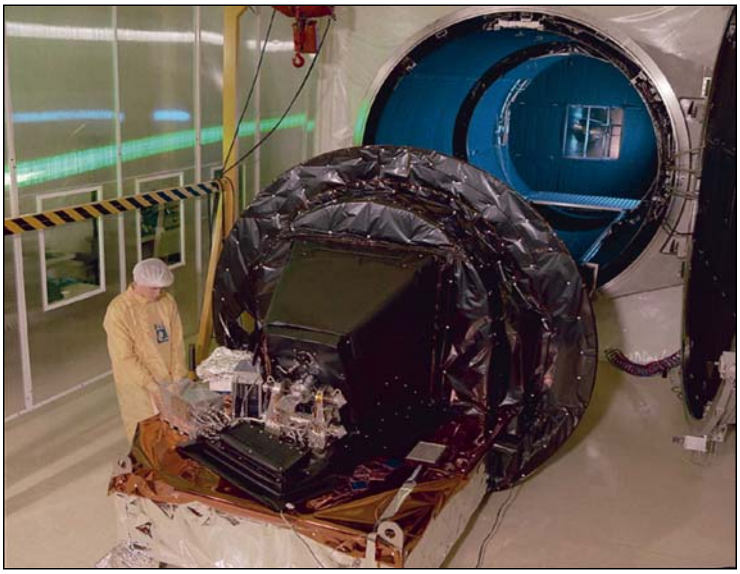


Figure 7.3.1 the ATSR space test facility at the Rutherford Appleton Laboratory, UK. (C. Mutlow)

Mutlow concluded by noting that the ATSR series provides a unique independent data set of exceptionally high quality. However, the continuity of the ATSR series is now uncertain as the AATSR is the last instrument and no follow on mission is currently planned. Given the relatively long lead time for space instrumentation planning, this will result, at best a discontinuity in the data record, or at worst no further data. Finally, Mutlow suggested that GHRSST-PP should consider using the AATSR as a reference data source of SST based on the design and stability of the instrument.

7.4 S. Casitas, P. Le Borgne and H. Roquet: Merged SST data products at Meteo France/CMS

Pierre LeBorgne introduced the main aim of the Mete France/CMS collaborative project which is *To provide the MERCATOR system with analyzed SST fields over the Atlantic,daily, at 0000UTC*. Within the project, the data processing system is split into the following component parts:

- **Data Collection.** In situ Buoy data are collected at 10:00 UTC. NAVOCEANO MCSST data are collected at 15:30 UTC, O&SI SAF data are available in real time and AMSR data are collected at 15:30 UT.

- **Pre-processing.** In this phase,. wind speed information, sun zenith angle etc are added into the data streams. Quality control is executed using minimum climatologic values. The pre-processing phase uses procedures to select single value data for each source referred to as “collated” data products. A final selection of data produces “merged” data products that are then used in an OI analysis procedure.

Collated data products are derived from data arriving between 1800 till 0600 that are quality controlled using wind speed with criteria set to wind speed thresholds of > 6 ms-1 by day and > 3 ms-1 by night. One collated field per source is then selected. Each collated data set has an associated data quality flag computed from a series of criteria including the number of observations within a cell, the proximity to climatological minimum SST values (computed from Pathfinder SST) and proximity to cloud.

The merged data products requested by the MERCATOR project are for SSTsubskin. In order to merge data form competing sources, a simple hierarchical rule is applied that selects in situ buoy data in preference to satellite data. The best quality data are then selected and if a conflict is found, AVHRR data are used in preference to GOES data. In addition, the data closest to 00:00 UTC are chosen if there is an additional conflict at this decision step. Merged data are then used in an OI procedure to derive a complete data field. Figure 7.4.1 shows example input data streams together with the corresponding output SST map generated by the processing system.

Analyzed data products have been validated using in situ buoy data in the Atlantic area. Table 7.4.1 shows the results of an inter-comparison of data products for the 24 November 2002. The greatest bias differences are found comparing the analyzed data products to the AMSR data (SD of bias is 0.82K) and the most favorable comparison is between the GOES-8 and the analysis.

Table 7.4.1 Comparison between the different SST data products used/produced by Meteo France/CMS. (P. LeBorgne).

St.dev. bias	*GOES-8*	*NOAA-16*	*NOAA-17*	*AMSR*	*ANALYSE*
GOES-8		*0.43*	*0.34*	*0.71*	*0.33*
NOAA-16	*0.11*		*0.31*	*0.68*	*0.42*
NOAA-17	*0.17*	*0.10*		*0.54*	*0.37*
AMSR	*-0.12*	*-0.10*	*-0.34*		*0.82*
ANALYSE	*0.01*	*-0.04*	*-0.08*	*0.31*	

The Meteo France/CMS processing system is designed for operational activities with a near real time data delivery of analyzed and merged SST data products over the Atlantic area 60N-60S in near real time (before 1200 day D+1). In January 2003 the geographical coverage will be extended to include 60S-l 90N with merged data products available worldwide. LeBorgne stressed that the demands of an operational system are immense even for the 24 hourly data products described here. GHRSST-PP must plan and work extremely hard to ensure that the systems that are built are operationally robust with redundancy and latency within the system to cope with day-to-day problems. Most of these problems are simple in nature (e.g., file format differences of data transmission problems) but exceptionally difficult to automate in terms of recovery procedures.

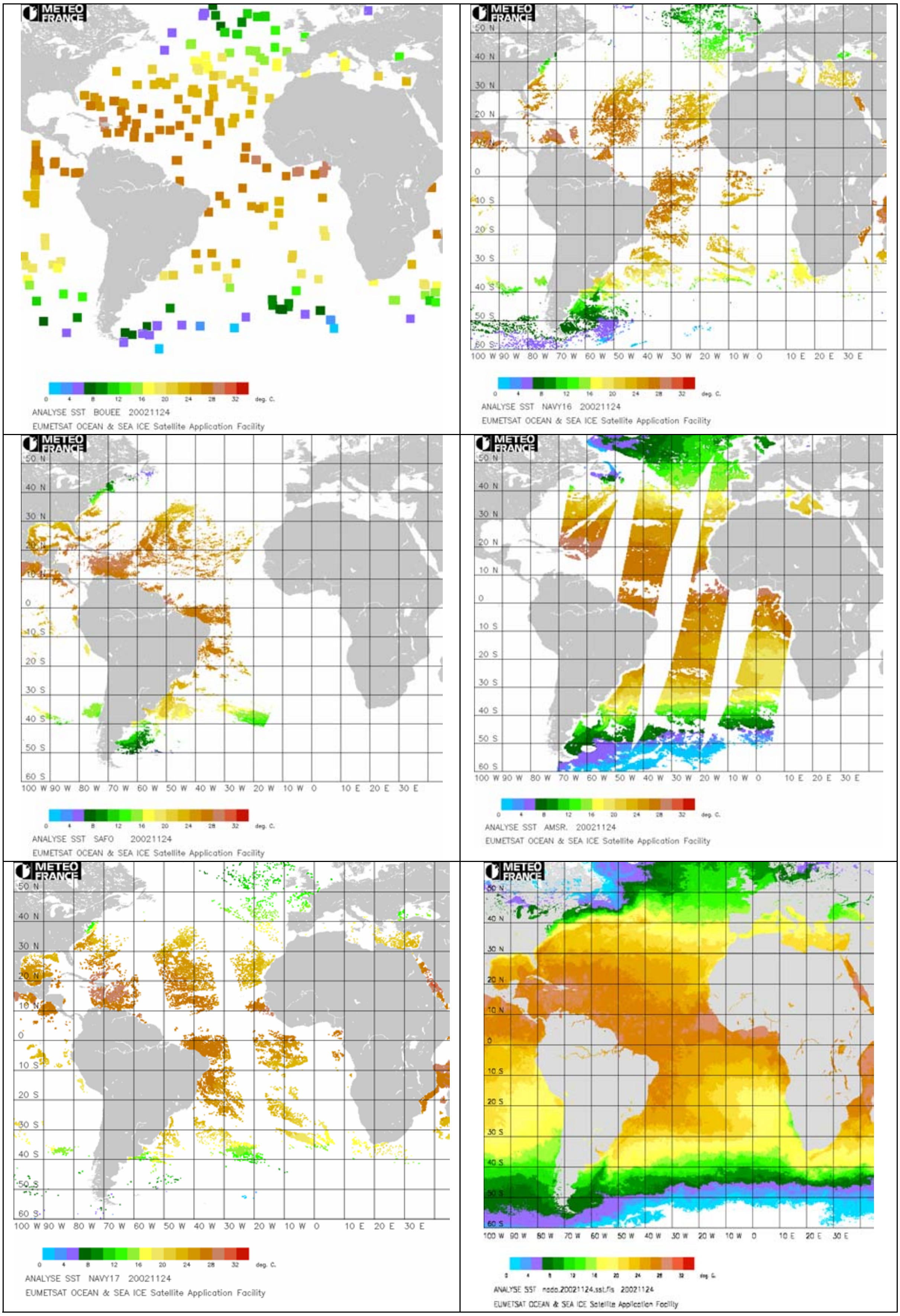


Figure 7.4.1 From top left to bottom right: (a) Collated in situ buoy observations, (b) N16 MCSST (c) GOES-8 MCSST (d) AMSR SST, (e) N17 MCSST (F0 analyzed data product (P. LeBorgne)

7.5 H. Kawamura: The present status of AMSR-E and ADEOS-II

Hiroshi Kawamura started by noting that the number of satellite sensors capable of measuring SST (and many other ocean parameters) is currently larger than ever before (see Figure 7.5.1). This is of great importance for GODAE which has been timed to coincide with the enhanced global coverage offered by earth observation satellite systems. In 2002-2003, three key satellite systems will be launched that provide unprecedented coverage of SST: ENVISAT (1st March 2002), EOS Aqua (7th May 2002) and ADEOS-II (November 2002).

Kawamura then moved on to a technical description of the Advanced Earth Observing Satellite-II (ADEOS-II) satellite and payload. ADEOS-II is the successor to the Advanced Earth Observing Satellite (ADEOS) and has been developed to acquire data for global climate change research, as well as for applications such as meteorology and fishery activities. ADEOS-II is also an International Joint Project which carries core sensors developed by NASDA and mission Instruments developed by national and international partners. The Core Sensors developed by NASDA are:

- AMSR (Advanced Microwave Scanning Radiometer)
- GLI (Global Imager)

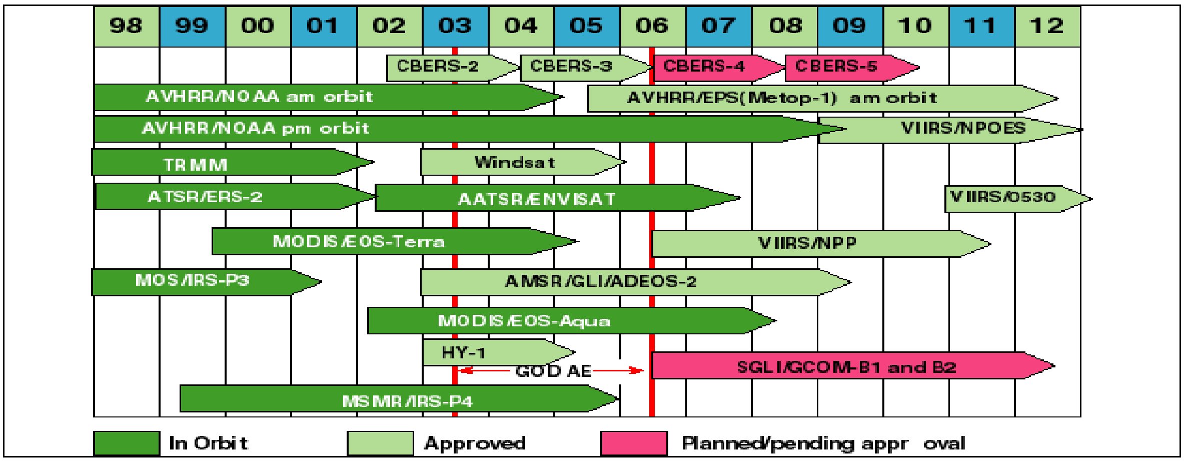


Figure 7.5.1 Schedule for satellite systems capable of measuring SST ((Patzard & Van Woert Version)

Sensors developed by international partners are:

- ILAS-II（Improved Limb Atmospheric Spectrometer-II）developed by the Ministry of Environment ,Japan
- SeaWinds Scatterometer, developed by NASA（National Aeronautics and Space Administration), USA and the JPL (JET Propulsion Laboratory)
- POLDER（Polarization and Directionality of the Earth's Reflectances）, developed by CNES（Centre National d'Etudes Spatiales）, France.

Kawamura focussed on the Advanced Microwave Scanning Radiometer (AMSR) sensor. AMSR observes the microwave energy naturally radiated from the Earth's surface and atmosphere. Regardless of day and night or weather conditions, it is capable of making high quality observation by monitoring the passive microwave emissions of the earth.

The main aim of the mission is to understand the global water and energy circulation by observing various geophysical parameters relate to water including Water vapor content, precipitation, sea surface temperature, sea surface wind, snow, etc. Figure 7.5.2 shows a schematic of the scan geometry employed by the AMSR sensor that has a ~1600 km swath with an mean beam footprint of ~50 km. the lower ~6GHz frequency channels (used for SST measurements) have a footprint of ~75 km although over sampling in both the flight and scan directions means that in practice a grid size of ~25 km is possible.

AMSR is not only important for SST measurements, but also for sea-ice products such sea ice concentration and several groups in Japan are working towards a new generation of sea ice data products having a spatial resolution of ~12 km and daily coverage. These data will be of use in the GHRSST-PP as the present sea ice data sets are at a much coarser resolution (~25 km).

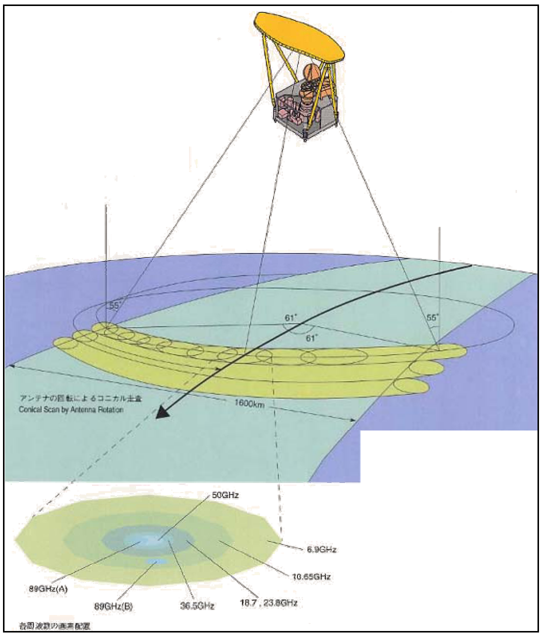


Figure 7.5.2. Scanning geometry of the AMSR sensor (NASDA)

Kawamura then moved on to describe the ADEOS-II Global Imager (GLI), the successor to OCTS onboard ADEOS. The GLI is an optical sensor developed for frequent and global observations by reflected solar radiation from the earth 's surface including land, ocean, cloud, and by infrared radiation for measuring physical characteristics of the sea surface. GLI is a multi-spectral instrument having 36 channels in the visible and near-infrared regions （375nm～12.5μm）. The ground resolution is 1 km at the nadir, part of the channels have a resolution of 250m at the nadir which will be used for observing vegetation and clouds.

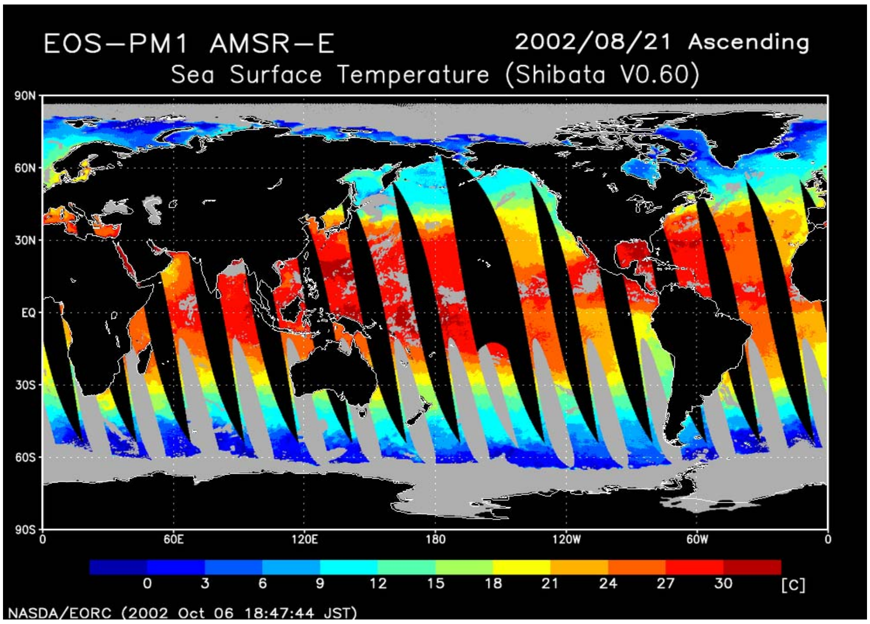


Figure 7.5.3. Preliminary SST retrieval from AMSR-E using the Shibata v0.6 algorithm (H. Kawamura).

The ILAS, POLDER, SeaWinds Scatterometer systems were then presented by Kawamura. Of particular interest is the possibility to use the SeaWinds scatterometer and the AMSR data together allowing a truly coincident wind speed direction correction to be made on the AMSR SST data using the scatterometer data. Currently, for AMSR-E (carried aboard the EOS Aqua) either model outputs or wind speed observations obtained several hours from the data are required to make this type of correction.

Kawamura then presented a overview of data flow for the ADEOS-II mission. Most operations are focused on the Earth Observation Centre Japan, with direct fast connections to Kiruna, Wallops and Alaska receiving station. Direct links to CNES and the USA are also necessary for the control and management of non-Japanese instruments (SeaWinds and POLDER).

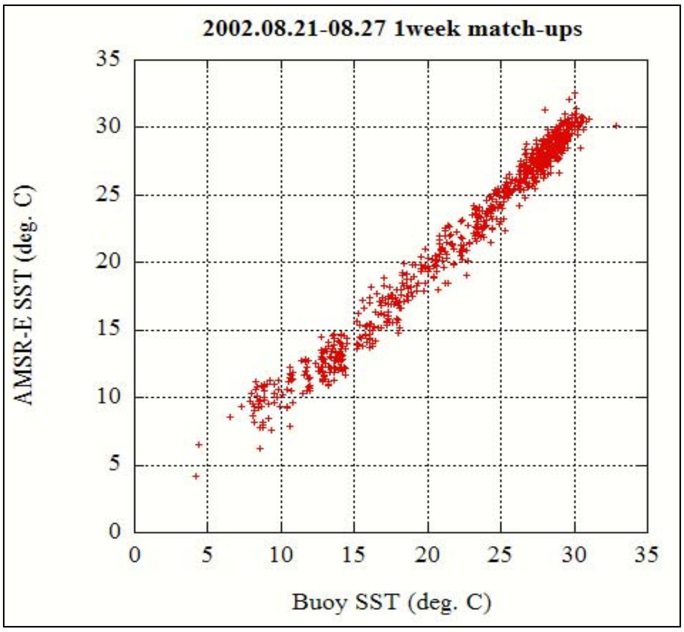


Figure 7.5.4 Preliminary validation of AMSR-E Shibata SST data using in situ buoys. (H. Kawamura).

Finally Kawamura concluded with a short summary of AMSR-E validation activities based on the first and recent acquisitions made by the AMSR-E instrument. Both radiometric and geometric studies are underway and initial results suggest that the AMSR-E system is performing well. Post launch NEΔT agree well with pre launch characterisation (even better in fact). Deep space counts are stable and agree well with expected values. Near contemporaneous SSM/I and AMSR-E Brightness temperature data obtained over the ocean agree well. Preliminary SST data have been retrieved form AMSR-E based on the Shibata (v0.6) scheme and are shown in Figure 7.5.3 below. A short validation data set has been collected that is based on available buoys and contemporaneous AMSR-E data. Preliminary results are shown in Figure 7.5.4 and suggest that the algorithm returns slightly warm SST in cooler areas (i.e. below ~10°C). However Kawamura stressed that these were preliminary data and there remained a considerable amount of research to complete.

7.6 C. Gentemann: Developments in AMSR-E/TRMM-TMI/TRMM VIRS fusion SST

Chelle Gentemann began by discussing the main advantages of blending/merging infrared (IR) and microwave (MW) SST data sets. Through blending an overall increase in final product accuracy is expected as the IR SST will be tied to MW SSTs for continuously updated calibrations. In addition there is more opportunity for new cloud identification schemes in infrared data sets based on MW information leading to better cloud removal in the IR SST data. One of the main drivers for merging IR and MW SST data is the better coverage afforded by the MW sensors. 60% of IR retrievals are thrown away due to cloud contamination which has significant implications in certain situations. For example, during large tropical storms/hurricanes, cloud cover can prevent retrieval of SST which is vital for accurate intensity forecasts. Furthermore persistent regional cloud cover (e.g., high latitudes) can prevent IR SST retrieval for extensive periods. There are also operational advantages including the automatic correction for volcanic aerosols/dust events and the ability to monitor the stability of IR retrieval coefficients.

Through merging of IR and MW data, Gentemann explained that more accurate bulk temperature estimates can be expected. Many IR SST algorithms rely on in situ match-ups to derive the algorithm coefficients via regression analysis on monthly/annual timescales. One major advantage of using MW SST to remove biases within the SST algorithm (as compared to using *in situ* observations) is that one obtains a large statistical data base in a very short time, and this database is global rather than being limited to the geographic confines of *in situ* observations. Given this database, the algorithm coefficients, which will be represented by slowly varying functions in time and space (on scales of months and thousands of kilometres) can be updated by continually regressing contemporaneous IR SST or brightness temperatures to the MW SST. This assumes that the MV SST is perfect, which is not the case and ignores any physical differences between the IR and MW SST (skin vs subskin). In addition, MW sensors can provide contemporaneous MW retrievals of water vapour content that should provide additional information for the IR retrieval process.

Gentemann then noted that there are considerable benefits in terms of long-term stability of the SST data record from space by undertaking merging activities. Understanding bias differences is critical to the development of a stable long-term SST record derived from multi-mission data sets. Figure 7.6.1 shows a time series of global monthly average SST from a number of satellite instruments. Biases in the IR MCSST SST record due to atmospheric aerosols are clearly visible as spurious cooling events due to volcanic eruptions in 1982 and 1991. These biases are absent in the Reynolds SST OI analysis because it is constrained by *in situ* measurements. The microwave channels used for SST retrieval are not affected by aerosols, and hence MW SSTs will be useful in inferring small temperature changes in the Earth's climate.

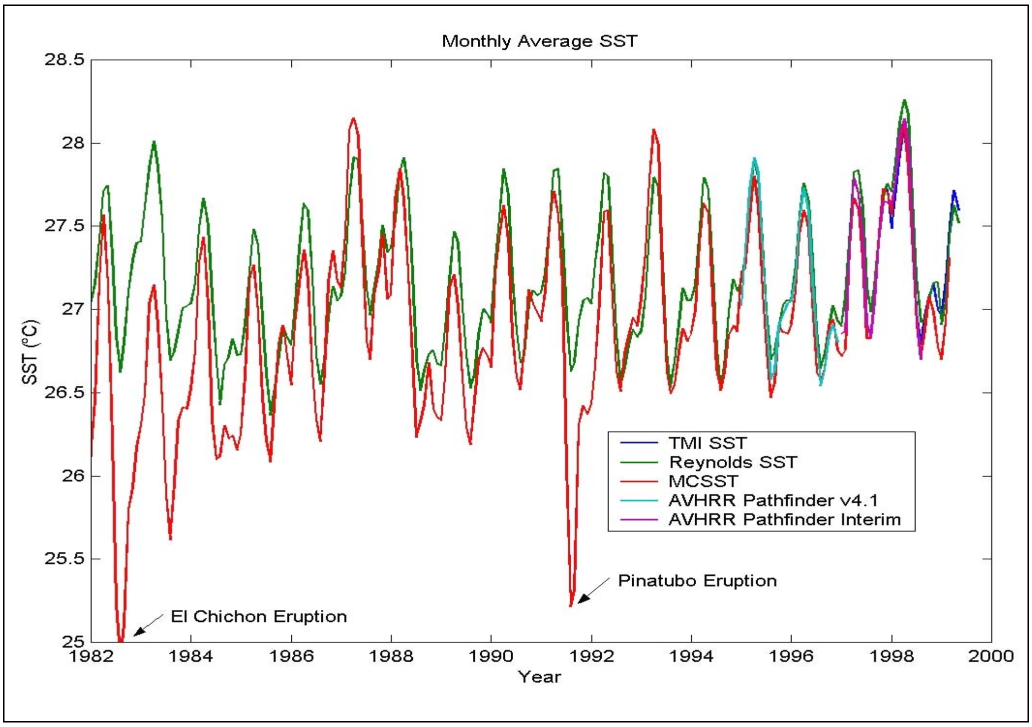


Figure 7.6.1 Time series of global monthly average SST from a number of satellite instruments (C. Gentemann)

There will be three satellite microwave radiometers in operation during 2001-2003 (TMI on TRMM, AMSR-E on Aqua, and AMSR on ADEOS-2). In 2 days, complete global coverage will be obtained, and one can construction a 2-day global map of microwave SST retrievals at a 50-km resolution. The IR SST retrievals can be sub-sampled to 50 km and compared with the microwave results and bias differences established. Gentemann noted that the inevitable question is whether the MW SST can be trusted as an absolute reference to remove biases in the IR SST. Past satellite microwave radiometers (including TMI) have experienced small calibration problems on orbit. However for the most part, these calibration problems have been correctable using post-launch calibration methods, leading to extremely reliable inter-annual and decadal time series. Two notable examples of this are the MSU air temperature time series from 1979-2000 [*Spencer and Christy*, 1990] and the SSM/I water vapor time series from 1987-2000 [*Wentz and Schabel,* 2000]. A very high confidence on the microwave technology is required to use MW SST as a bias reference in this way but the experience of TMI (and the ability to recognize and correct for problems during the mission) is encouraging.

Gentemann then described the methodology currently on trial to merge TRMM TMI and AMSR-E SST data. The method first inter-calibrates data for TMI/AMSR-E and diurnal warming / nocturnal cooling is subtracted using a sensor specific empirical model. The daily minimum temperature is calculated at 7am and data re merged using the optimum interpolation scheme following Reynolds and Smith (1994). The current OI scheme assumes globally invariant correlation scales in time/space. Finally, in areas of diurnal warming, the diurnal amplitude is calculated using a physical model. Figure 7.6.2 shows an example product derived using this methodology, and figure 7.6.3 shows a detailed image for the southern Pacific and Atlantic Ocean.

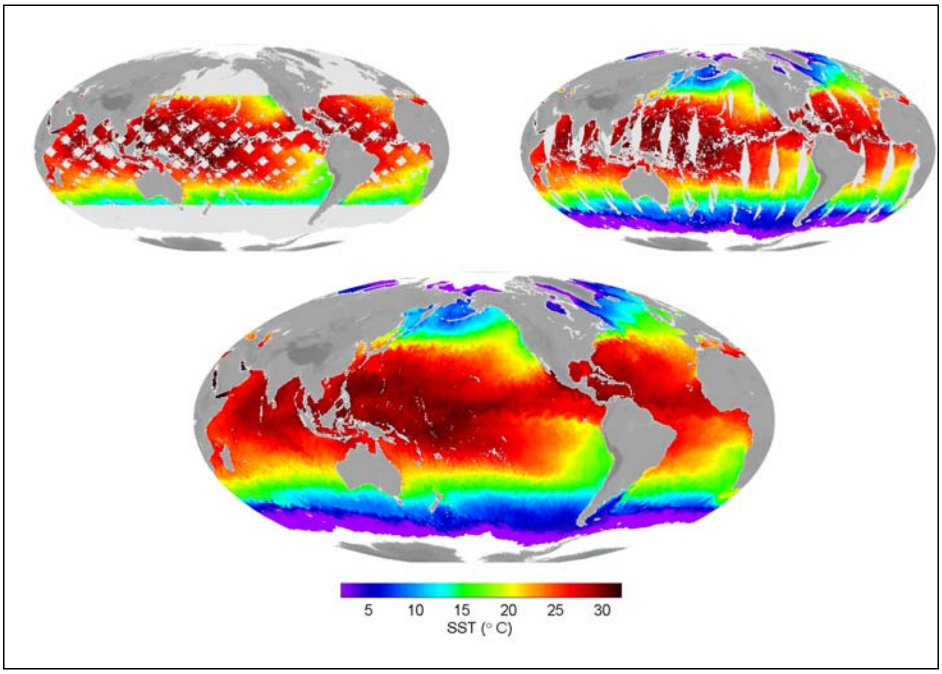


Figure 7.6.2. Example data product derived from a combination of TMI and AMSR-E SST, September 26th 2002. (C. Gentemann)

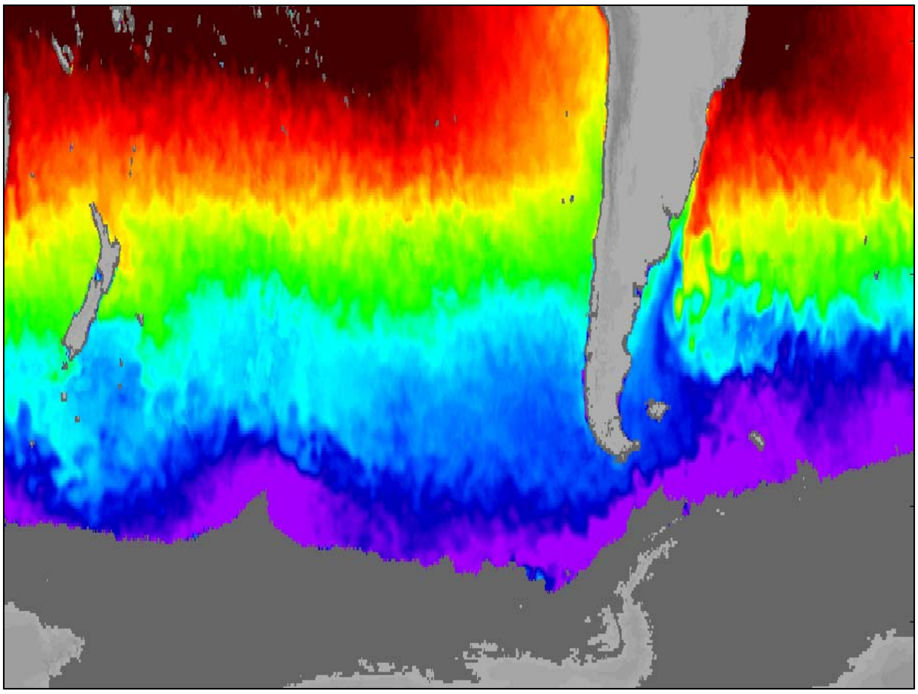


Figure 7.6.3. Detail taken from the merged TMI+AMSR product shown in Figure 7.6.2 in the southern Pacific and Atlantic Ocean. (C. Gentemann)

Clearly evident in Figure 7.6.3 is the complete coverage afforded by the MW SST data set with reasonable detail revealing the Brazil-Falklands current system and meso-scale activity. Typically, monthly mean data are required to completely image this particular region due to persistent cloud cover whereas this image uses data from two sensors obtained in a single day. Several modifications to the basic merging scheme are currently being implemented including the use of location and time specific decorrelation scales for the OI procedure and a more thorough error characterization (High Wind / Diurnal Model Errors / Water Vapor).

Gentemann then reported on the error characterisation of the TMI SST based on contemporaneous match-up data using in situ buoys. Using TAO and PIRATA tropical moored buoys negligible bias (< 0.1 K) is found with rms deviations of ~0.5K. However, using NDBC buoys (predominantly located around the US offshore coast), the bias is 0.3K with an rms of 0.94K. Gentemann commented that the larger standard deviations of buoys located along the eastern US coasts are likely due to the small-scale temporal and spatial variability common to buoys in this Gulf Stream region. The warm bias is likely due to the increased side-lobe contamination from land.

Gentemann then noted that wind speed, water vapor and atmospheric cloud can all be a source of error in the microwave SST algorithm. By simultaneously deriving these parameters, it is possible to remove any effects each may have, leaving no dependence of each parameter on the SSTs. In the case of TMI, no remaining effects on SST caused by wind speed, water vapor or cloud are seen when this analysis is done. The residual (found by subtracting Reynolds SST or buoy SST from TMI SST) is very small (–0.07K, with an SD = 0.57K). There small bias reflects the ability of the algorithm to accurately retrieve each parameter adding weight to the robustness of microwave retrievals in the presence of water vapor and cloud (which should help parameterize errors in infrared SST fields).

In addition to the TMI instrument, the TRMM satellite carries an infrared scanner (VIRS) capable of accurate and independent SST retrievals. VIRS data are collected over a swath width of 760 km at a resolution of 2km and are coincident with TMI data. Remote Sensing Systems is currently testing various IR SST retrieval schemes for the VIRS sensor. 4 algorithms are being tested:

1. NLSST: a1 + a2*T4 + a3*(T3-T5)*SST + a4*SecTh
2. SHIBATA:a1+a2*T4+a3*(T4-T5)+a4*(T4-T5)*SecTh+a5*(T3-T5)+a6*(T3-T5)*SecTh
3. RSS1: a1 + a2*T3 + a4*T4 + a5*T5 + a6*WV + a7*WV*SecTh
4. RSS2: a1 + a2*T3 + a4*T4 + a5*T5 + a6*SST*(T3-T5) + a6*WV + a7*WV*SecTh

Regression coefficients are determined using 1 year of collocated VIRS and TMI data. Following cloud masking and application of the SST algorithms, orbital VIRS SSTs at a spatial resolution of 4 Km are produced that are finally averaged to daily maps of gridded VIRS SSTs having a spatial resolution of 12.5 Km. Initial results using independent VIRS together with collocated TMI data show that the RSS1 algorithm has an rmse=0.7K (see Figure 7.6.4)

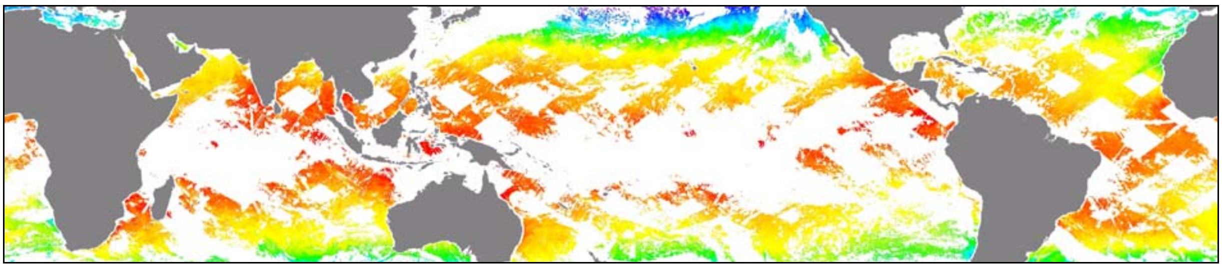


Figure 7.6.4 TRMM VIRS SST image using the Remote Sensing Systems NLSST formulation. The algorithm is derived form contemporaneous TMI MW SST. (C. Gentemann)

During this process, it became clear that the TMI could provide useful information for cloud masking of the VIRS data based on correlations between IR Channel difference (ΔTB) and TMI water vapor products. This is still work in progress and will be developed over the coming months.

7.7 A. Harris: Innovative strategies or cloud removal within the GHRSST-PP

No Abstract or summary available.

7.8 C. Gentemann: Diurnal signals in satellite SST measurements

Gentemann presented work on the implications of diurnal warming on satellite data noting that a more complicated relationship between IR/MW/buoy SSTs exists that has been previously supposed. The approach taken was to derive sensor specific empirical models through comparison of empirical models to physical models (providing an adjustment capability) that can be used to calculate a daily minimum SST (requiring an empirical model) to provide daily diurnal amplitudes.

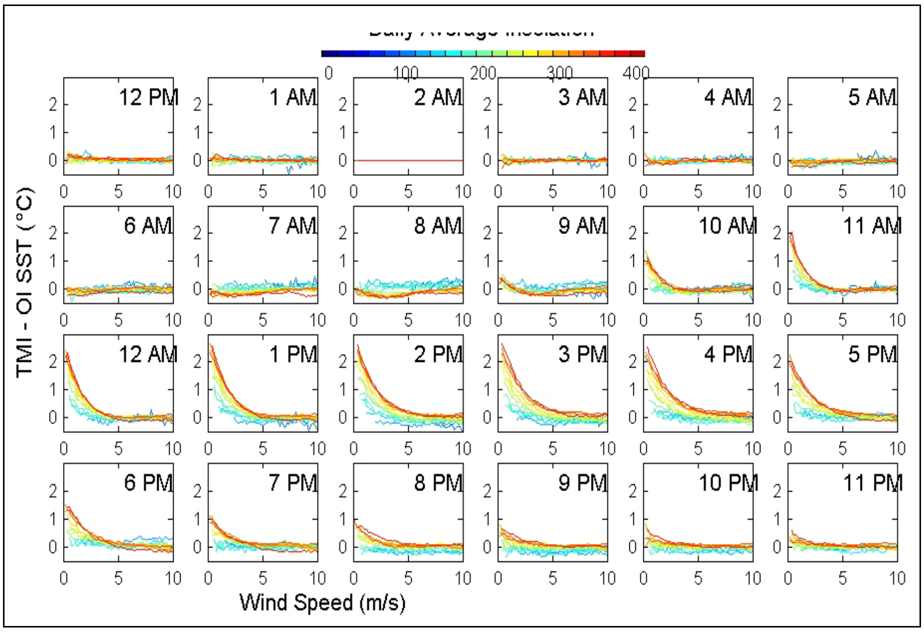


Figure 7.8.1 Cool-skin adjusted TMI-Reynolds OI SST as a function of wind speed for the global domain for 2 hourly periods covering the period 1998-2001. The colour of line indicates the mean daily solar insolation (0-400 Wm^{-2}). (C. Gentemann)

Genteman n presented examples of clear diurnal signals seen with ATSR and Pathfinder data when matched to in situ buoy data at low wind speeds reported by Donlon et al (1999. A similar analysis was then performed using TMI SST collocated to in situ buoy data in the tropical Pacific. Reynolds OI SST was subtracted from near contemporaneous TMI SST data for the global domain and a normalisation correction applied for cool effects by subtracting the differences found at 2 AM from all other data. The resulting data, for 1998-2001, were then plotted for each 2 hourly period within a 24 hour window and are shown in Figure 7.8.1. This figure is interesting in that diurnal variations are seen well into the nocturnal period (e.g., 12 AM, top left panel) with little variability between 1 and 8 am. Note that the TMI is limited to the 40S-40N region. Measurable diurnal warming may commence as early as 8 am and is clearly seen at 9 am in conditions of strong solar warming.

These results have considerable implications for the derivation of error statistics using in situ observations and for the merging of satellite SST obtained from different sensors at different times of the day. Gentemann explained that sensor specific empirical models of diurnal warming had been derived from these data using non-linear least squares regression.

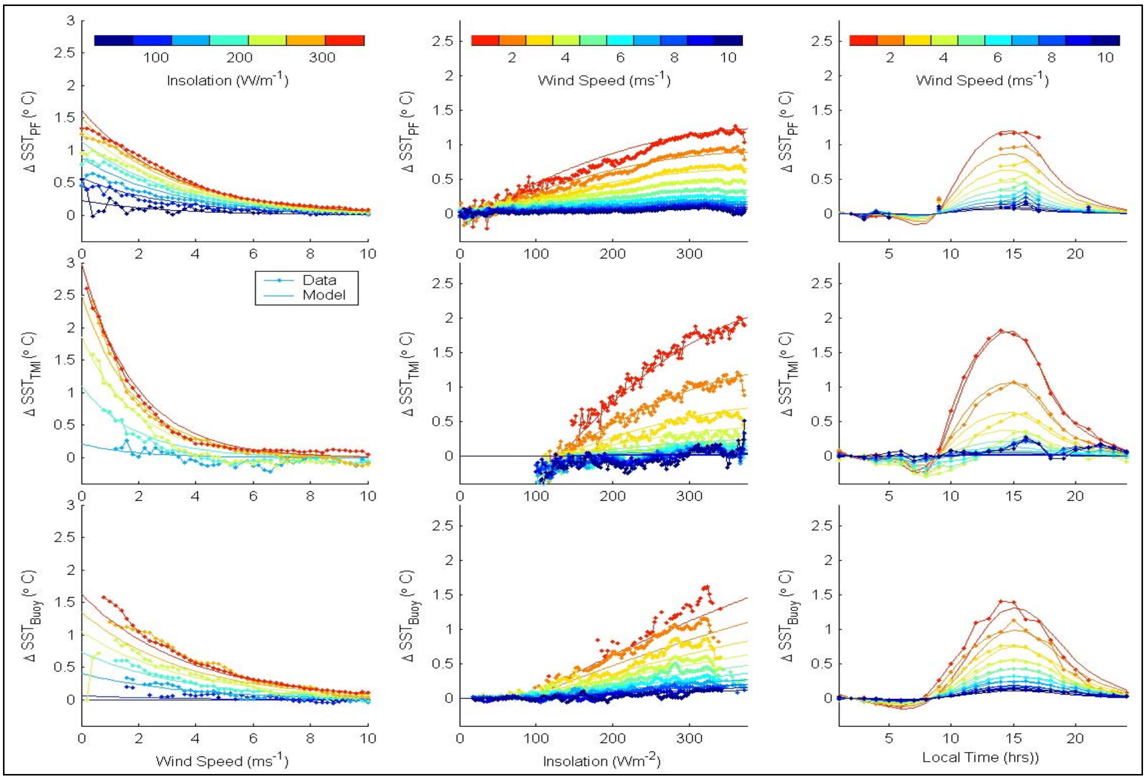


Figure 7.8.2 Comparison of data and empirical model at 2PM. The left column shows Pathfinder SST-Reynolds OI SST, TMI SST – Reynolds OI SST and In situ SST – Reynolds OI SST as a function of wind speed. The centre column shows the same ΔSST quantities but as a function of insolation and the final column shows the relationship with time. Data are shown as heavy curves while model results are shown as light curves. (C. Gentemann)

A linear dependence on insolation and exponential dependence on wind speed and a time dependence described by a five-term Fourier series was used to develop the models which are shown in Figure 7.8.2. Based on these data, where solar heating is weak, below 132 Wm^{-2}, there is no discernable diurnal signal and the model is set to zero.

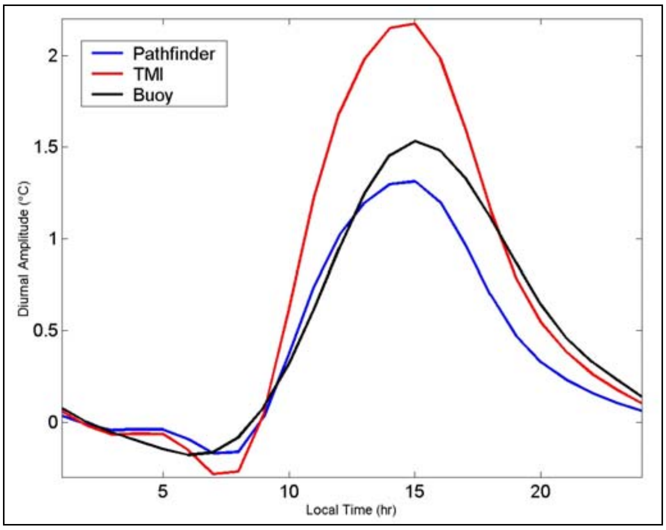


Figure 7.8.3. Sensor specific empirical models of diurnal warming for TMI, Pathfinder and in situ buoys for a wind speed of < 1ms^{-1}. (C. Gentemann)

Figure 7.8.3 shows the modelled diurnal signal for the pathfinder, TMI and in situ buoy models for a wind speed of < 1ms^{-1}. The differences between each model are related to imperfections in each of the sampling systems including algorithm errors (e.g., diminished response of the TMI due to wind cross-talk removal), geographic validity of each algorithm (e.g., the Pathfinder SST algorithm is derived mostly from collocations in the low-wind speed tropical regions) or physical reasons that are currently not understood.

Diurnal corrections based on these models have been applied to Pathfinder SST data for several years. Figure 7.8.4 shows the results obtained from this procedure for 1990 and 1992 Pathfinder SST data. Day-night differences and variability are significantly reduced in most latitudes when applying an additional diurnal correction. However some differences remain due to the limitations of the diurnal model itself. Nevertheless, these results highlights the need for GHRSST-PP to account for diurnal variability prior to merging and combined analysis.

Genetmann concluded by describing the future work planned to improve and extend the current scheme. This includes:

- Calculate the model coefficients using Kawai/Kawamura and Insolation data
- Model Error: Skin / bulk in situ data from Cruise / Buoy comparison to determine errors in empirical / physical models
- Consider the implications of clouds on the diurnal signal (MW sensors can see through cloud)
- Extend the procedure to other sensors

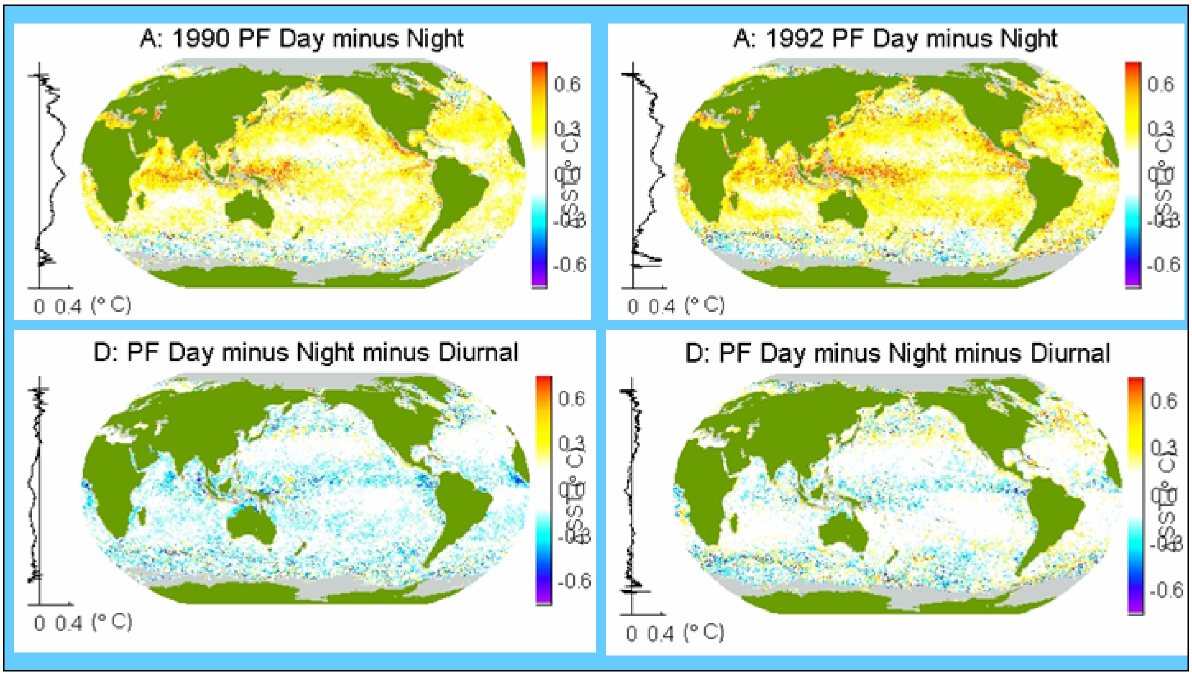


Figure 7.8.4 Diurnal warming manifest in Pathfinder SST data in 1990 and 1992. (A) and (B) computed day-night SST for 1990 and 1992 respectively using pathfinder data. The mean latitudinal deviation is shown to the left of each plot. (C) and (D) as for)A) and (B) except with the empirical diurnal warming correction applied. (C. Gentemann)

7.9 P. LeBorgne: Characterising the error in GHRSST-PP data products

Pierre Le Borgne noted that in the first GHRSST-PP ISDI-TAG report, Confidence statistics were discussed as

> *"…estimate of uncertainty derived during production of the product…*
> *...bias and standard deviation…*
> *…derived from validation of similar recent measurements…"*

Ideally, each satellite pixel should have its own error statistic that is used by merging procedures and in data assimilation. LeBorgne suggested that an 'error statistics' equates to a bias and standard deviation measure. But a significant problem arises when one considers which references are these measures based against? LeBorgne suggested that this could be achieved by a characterization of production condition including (for example)

- Cloudiness
- Latitude
- Season
-

Typically, contemporaneous buoy observations are used to quantify 'errors' in satellite data. In this scheme problems arise due to the definitions of different SST data (SSTskin, SSTsubskin) and a simple difference between buoy and satellite pixel is open to question. Furthermore, only a limited number of accurate in situ SST data are available.

LeBorgne then presented the scheme used at Mete France and the Ocean and Sea Ice Satellite application facility (O&SI SAF) to ascribe numerical error values to satellite SST data. However, there are insufficient in situ data to derive errors for every pixel. This a sparse high quality population of in situ observations must be related to a large wide geographically spread population of satellite data. The scheme used at the SAF depends on two main criteria:

- The proximity of an SST pixel to the nearest cloudy pixel (sensor specific)
- The deviation from a sensor specific 'minimum SST' climatology (i.e., the minimum climatological SST value expected in a given place and date. (St Meteo France this is based on a 10 year atlas of Pathfinder SST).

Table 7.9.1 Characterization of the production conditions with confidence levels at Meteo France/DP/CMS. (P. LeBorgne)

Temp. Threshold	acceptable		excellent
Tqual		bad	
Tnear			good
Tfar		cloudy	
	d1	d2	Distance from cloud

Confidence level as a function of temperature and distance from cloud

0="unprocessed", 1="erroneous (cloudy)", 2="bad", 3="acceptable", 4="good", 5="excellent"

The scheme considers cloud contamination as by far the most important source of error for satellite SST. Furthermore, the scheme must be relatively 'cheap' in terms of data processing and sophistication as the SAF provides an operational system that cannot be burdened with exhaustive computations. In the scheme, each pixel is classified according to the two criteria above and a numerical 'confidence' value is ascribed based on Table 7.9.1.

Pixels are classified on a numeric scale ranging from 0 (unprocessed) to 5 'excellent data'. In this scheme, two sensor specific distance from cloud thresholds and three temperature thresholds are required to define a confidence level. The scheme could be extended to include other effects such as diurnal warming events. Sensor specific thresholds are required due to the different characteristics of sensor geometry. Figure 7.9.1 shows an example application of the scheme to a GOES image in the Atlantic Ocean.

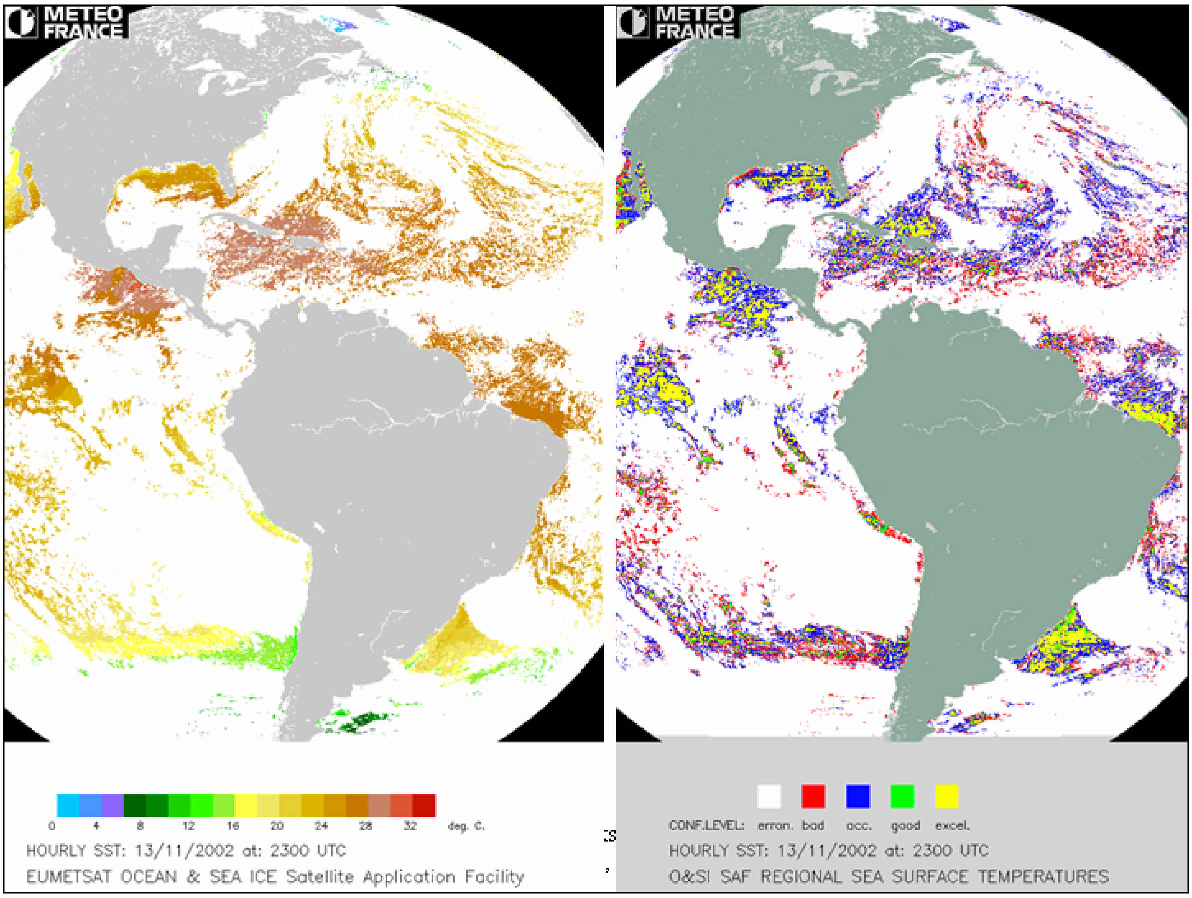


Figure 7.9.1 (Left) GOES MCSST for 13/11/2002 at 23:00 UTC. (Right) confidence value for the image data shown in panel (a). (P. LeBorgne)

It is clear from Figure 7.9.1 that the use of confidence flagging provides additional quality control in formation for areas that would otherwise be considered good SST retrievals (e.g., the area off the coast north of the River Plate estuary, Uruguay/Brazil).

LeBorgne then explained that based on confidence level, a bias and SD error statistic can be derived for each pixel. In this scheme, a match-up database (MDB) of contemporaneous in situ and satellite data are used to define statistical relationships between the confidence level ascribed to a given pixel and the mean error statistics of the entire MDB for that confidence level. Figure 7.9.2 shows the result of this analysis for the GOES-8 MDB over the period 10/2001-10/2002 using a validation box of 5x5 pixels centred on the buoy location. Both day and night-time data have been separated in the analysis. Clear relationships are evident in bias error but SD remains fairly constant. The scheme can be extended to look at seasonal or geographic location and provides a powerful tool to extract the greatest benefit form a limited in situ dataset and provide numerical error statistics for each satellite pixel.

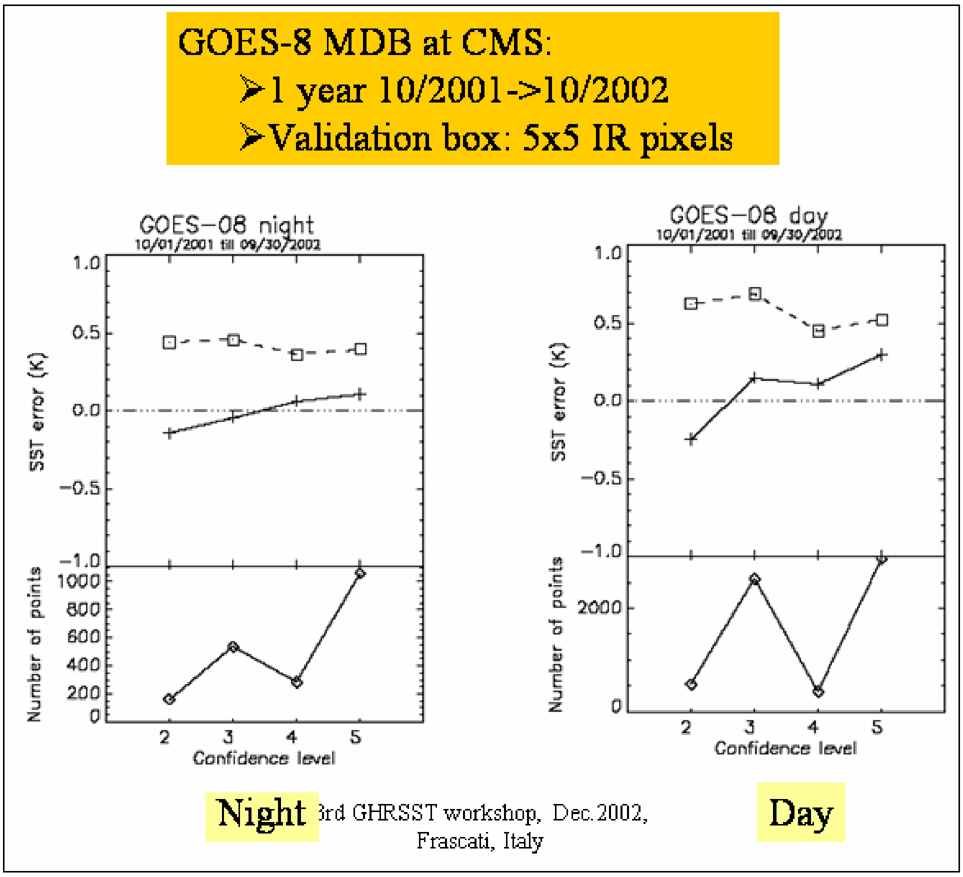


Figure 7.9.2 Relationship between Bias and standard deviation and confidence level derived for 1 year of GOES-8 data (10/2001-10/2002). (P. LeBorgne)

LeBorgne concluded that this method could be used by GHRSST-PP to provide an operational scheme to produce error statistics for every output SST pixel value. In this case, errors would be referenced to buoy measurements. A characterization and prioritization of the basis for confidence level would be required. At Meteo France the prioritization is relative to cloud clearing and minimum SST climatology but other options are possible. Finally there is some evidence that the relationship between confidence value and error has some variability with latitude and season in the GOES-8 case. Further investigation will determine if other sensors have similar characteristics.

7.10 C. Merchant: Radiative Transfer modelling limits and Capabilities

Chris Merchant began by outlining the motivation for this work which is based on the need to obtain accurate, long term SST data sets with a wide geographic coverage to determine if the ocean is warming. Merchant presented the main statistics of validation of satellite SSTs produced at CMS for a number of sensors (shown in Figure 7.10.1).

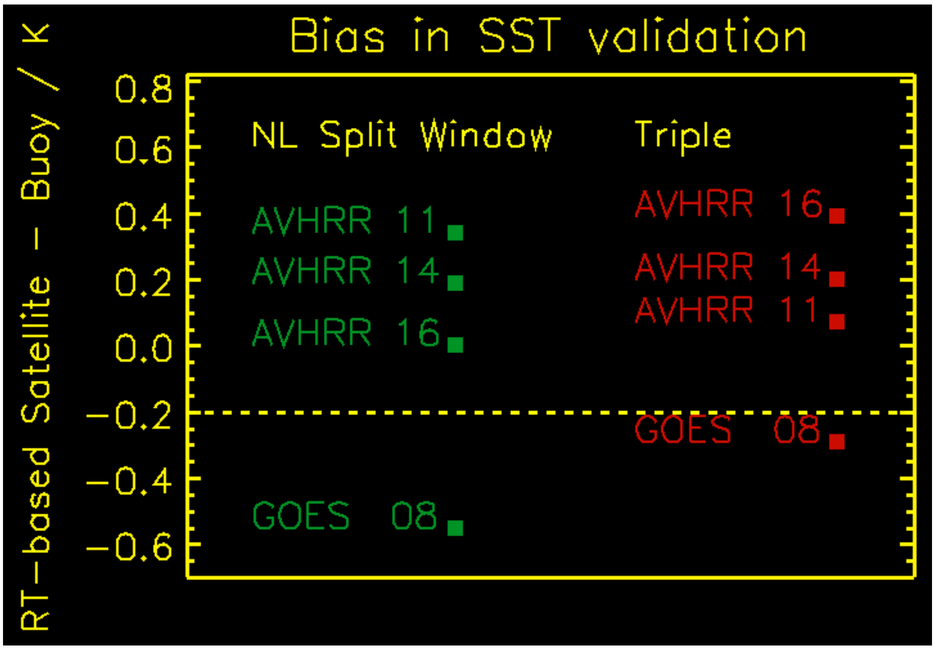


Figure 7.10.1 The mean satellite minus buoy SST in validations for four sensors -- three AVHRRS and a GOES (C. Merchant).

There are two retrieval algorithms: non-linear split window, which would typically be used for daytime retrieval, and 'triple', i.e. an algorithm using 3.7 as well as 11 and 12 um channels which is used only at night. In this exercise, however, both have been applied to the same night-time data, so that direct comparisons between the performance of the two sorts of retrieval can be made. Retrievals are based on radiative transfer modelling and should therefore estimate the radiometric temperature, which for IR is negligibly different from the interface temperature. Since these are night time data, the 'correct' answer for the retrievals should be about -0.2 K to account for the skin effect. However, the size of the biases obtained are of order a few tenths of Kelvin. Secondly, the spread of bias between sensors is greater for split window than for triple window scheme.

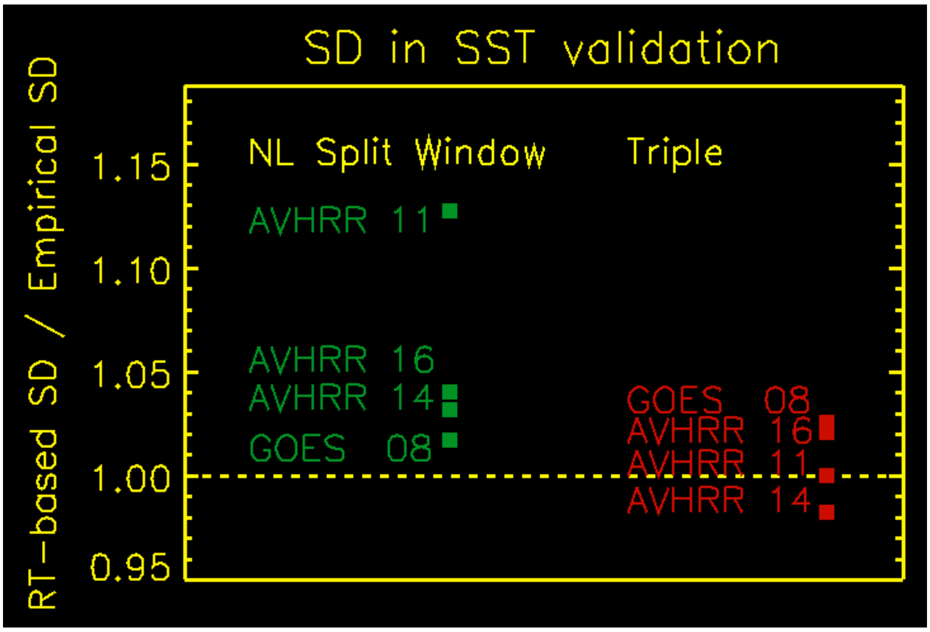


Figure 7.10.2. the SD of radiative transfer based (RT-based) retrievals, divided by the 'empirical SD' – see text for explanations. (C. Merchant).

In addition to bias, there is also a need to understand and quantify the scatter of retrievals, typically measured by standard deviation. Figure 7.10.2 shows the SD of radiative transfer based (RT-based) retrievals, divided by the 'empirical SD'. The empirical SD is an estimate for these data of the SD value derived by regression analysis between matched satellite brightness temperatures against the in situ SST measurements. Half of the data are used to define empirical coefficients that are then applied to the remaining data.

If the RT does equally well compared to the regression approach a ratio of one is expected. Instead, RT-based coefficients are giving results within a few percent one, i.e., little larger than the SD that would be obtained empirically. There is one exception where the comparison is rather poor (AVHRR 11), for which there is no explanation. The same data can be presented by expressing the 'extra' error from using RT, as an independent error in addition to that obtainable using empirical means. This is shown in Figure 7.10.3.

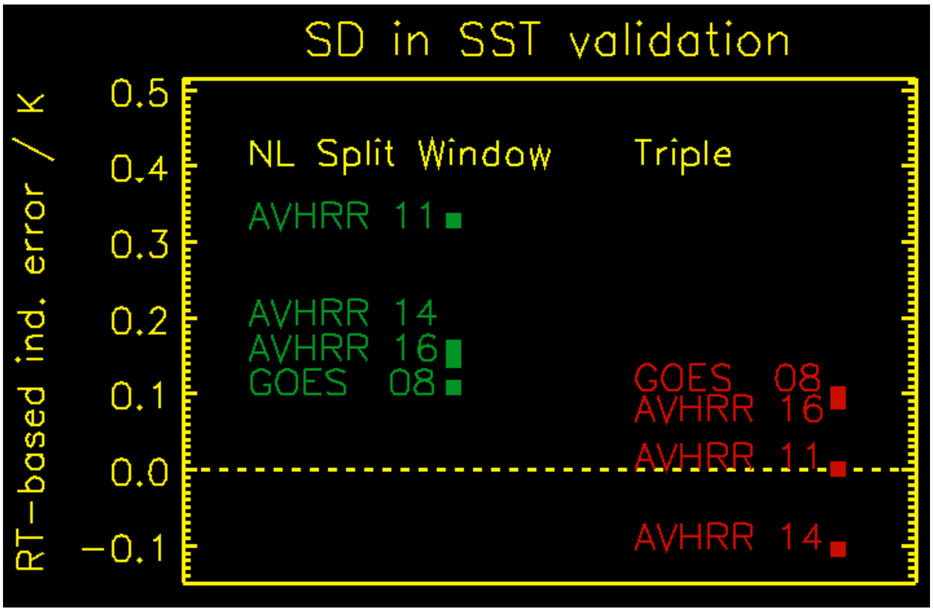


Figure 7.10.3 Same data as in Figure 7.10.2 expressed as an independent error above that expected from regression only algorithms. (C. Merchant)

Given that errors add as the square root of sum of squares, the 'extra' error from using RT of order 0.1 K is very small. It should be noted that a subset of the validation data set has been used to estimate the empirical coefficients. This isn't really a fully independent test for the empirical coefficients, because the geographical distribution of the two subsets is common, etc. In contrast, the RT-based coefficients are globally defined, not just where we happen to have in situ measurements. So, given results as close as this, it would be difficult to say which approach, RT or empirical, would give a better SD for a global SST.

Based on these results two obvious questions arise:

- Why is bias non-negligible while scatter is near-optimal?
- Will better (future) RT modelling improve the biases?

Merchant explained that Radiative Transfer Modelling (RTM) is a function operating on parameter inputs and atmospheric profiles and associated SST that are output. These are then regressed against the corresponding SST. When applied to observed brightness temperatures the coefficients give SST estimates. Typically, SST is formed as offset plus linear combination of brightness temperatures with some variations depending on satellite view angle or climatology or 'first guess' the SST value as extensions of the general method.

However, the SST retrieval coefficients themselves have errors due to imperfections in the RTM that are mean and variable errors over many SSTs and atmospheric profiles. The origins of the errors arise due to origins incomplete physics and the numerics within the RTM itself, errors in spectroscopic parameters and errors associated with instrumental characteristics.

The bias in RTM simulated brightness temperatures is at least 0.1 K, based on the discrepancy between models applied to the same profiles with a few different RTMs. This could be an underestimate, given that the models tend to have the spectroscopic parameters in common. The variable element of the model error tends to be smaller than the mean associated with varying a certain parameter. Basically, the error in the output from a parameter error tends to affect all simulations similarly, and the variable component of error is the residual. This is not true for parameters related to water vapour. Modelling of radiative transfer of water vapour is particularly critical because it is so variable in the atmosphere and is loosely correlated with SST. One of the key parameterizations is that of the water vapour continuum absorption. Briefly, there have been three updates to the standard CKD continuum over the past several years: 2.2 in mid 90s, 2.4 a few years ago and just out 'MT-CKD'. These are negligibly different for SST channels for example, MT-CKD involves decreasing the self-continuum absorption by 5%, but this is compensated by an increase in the foreign-continuum, and the SST impact is well below 0.1 K. It could be argued that window-region water vapour modelling has converged.

It can be shown that the error in weighting SST coefficients depends only on the variable component of the RTM error. In simulations of how error in coefficients feeds through to effects on SST, it can be shown that the effect is to increase SD by a few % -- which is just what is observed in Figure 7.10.2. the offset coefficient has an error that only depends on the size of the mean RTM error. If the magnitude of this error can be characterized by 0.1 K for each channel, then the error in the coefficient turns out to be the square root of the sum of the squares of the weighting coefficients times that mean error. The role of the offset is to bring the retrieval to zero bias, so it follows that an error in the offset ***IS*** the mean bias. Split window coefficients typically have a sqrt(sum a^2) of order 4, and so this would predict biases in split window retrievals of order +/-0.4 K. For 'triple' the coefficients are generally smaller, giving expected biases of the order of +/-0.2 K. This is consistent with the results shown both in terms of the magnitude of the biases seen there, and the lower spread for the triple than for the split window results.

The implications of this are that:

- For RT-based SST, consistency at ~0.1 K level only if simulations are absolutely accurate to ~0.03 K
- Offset adjustment to buoys is necessary for all sensors / algorithms

In order to correct the retrieval only the highest quality match-up data should be used that has been filtered to minimize the impact of geophysical skin-bulk variability and diurnal variability where decoupling between the satellite brightness temperature and subsurface temperature could have occurred. A recommended adjustment of -0.2 K (based on buoy observations using night-time only matches filtered to the higher wind speeds where diurnal warming and cool skin effects are minimum) is suggested for SSTskin retrieval. The adjustment should be to 0.0 K for tuning a SSTdepth retrieval scheme.

Finally Merchant explained that this work did not undermine the use of RTM for SST algorithm derivation but highlighted some of the errors that are apparent when approaching the limit of accuracy for the data used within the scheme. RTM is still an excellent tool:

- Pre-launch capability giving small biases
- Global definition of retrieval of a well-defined geophysical parameter
- It avoids danger of over-fitting regression
- Provides a means to simulate, assess and correct biases (regional, view-angle etc)
- It can build in tolerance to aerosols, etc
- RT informs cloud-screening effectively

Appendix 1 Agenda

December 2nd 2003

08:30	**Registration**	
09:00	Welcome and local arrangements ____	**Olivier Arino**
09:05	Outline of Workshop objectives and agenda ____	**Craig Donlon**
09:10	Opening of the third GHRSST-PP workshop ____	**Stephen Briggs**
09:30	Overview of the GHRSST-PP Implementation Plan ____	**Craig Donlon**

>>>SESSION 1 > The GHRSST-PP Applications and User Services (AUS)

09:40	D. Llewellyn-Jones: Sea Surface Temperature Data for the detection of Global Change	**I Robinson**
10:00	P. Bahurel: Application of GHRSST-PP data products in MERCATOR	
10:20	H. Cattle: CLIVAR and the GHRSST-PP	
10:40	Session summary	
10:50	**Coffee break**	
11:05	P. Yves-Le Traon: Applications of GHRSST-PP data products in MERSEA	**I. Robinson**
11:25	R. Santoleri: Mediterranean Forecasting System: results and prospective of satellite sea surface temperature assimilation	
11:45	W. Emery: Using GHRSST-PP data products in Maximum Cross Correlation (MCC) ocean current mapping	
12:05	H. Kawamura: The Coastal Ocean Observing Panel (COOP) and GHRSST-PP	
12:25	M. Drusch: Requirements for future SST data sets from the ECMWF perspective	
12:45	Session summary	
13:00	**Lunch break**	
14:20	S. Pouliquen: CORIOLIS: A French Project To Collect And Qualify In-Situ Data For Operational Oceanography	**B. Emery**
14:40	U. Send: In situ observations in the GHRSST-PP	
15:00	A. Hines: Applications of GHRSST-PP products in FOAM	
15:20	E. Chassignet: Application of GHRSST-PP data products in GODAE.	
15:40	Session summary	
15:50	**Coffee break**	
16:00	S. Eastwood: Operational use of regional high-resolution SST in a coupled ice-ocean model at Norwegian Meteorological Institute.	**B. Emery**
16:20	I. Barton: Fish and Farm Management in Australia Using SST	
16:40	Session summary	
16:50	**Summary: Applications of GHRSST-PP data products** ____	**C. Donlon**
17:10	Meeting Close	
17:15	GHRSST-PP Science Team Meeting (1 hour) ____	**Science Team**
18:15	**ENVISAT Ground Segment visit** ____	**P. Giles**
19:30	**Social dinner at the Hotel Villa Vechia** ____	**All invited**

December 3rd 2003

>>> SESSION 2 > GHRSST-PP internal component project summaries

H. Kawamura

08:30	H. Kawamura: Towards the Japanese RDAC: The NGSST project and its second version.
08:50	G. Wick: A proposal to NASA for a USA RDAC
09:10	O. Arino, Ian Robinson & P. LeBorgne Towards a European RDAC: The Medspiration project
09:30	N. Rayner: GHRSST-PP and Climate data sets
09:50	K. Casey: The User Information Services re-analysis project (UIS-RAN)
10:10	**Session summary**
10:40	**Coffee break**

C. Mutlow

11:00	S. Hankin and F. Blanc: The GODAE Data Sharing Pilot Project
11:20	E. Armstrong: The GHRSST-PP Master Metadata Repository (MDR)
11:40	J. Vasquez and E. Armstrong: Towards the GHRSST-PP User Information Services Data Active Archive Center (UIS-DAAC) and Data Product Server (UIS-DP)-The PODAAC Experience
12:00	J. Vasquez: The GHRSST-PP Diagnostic Data Set
12:20	C. Donlon, S. Pinnock, and Ed Armstrong: Implementation of the GHRSST-PP high resolution Diagnostic Data Set (HR-DDS)
12:40	Session summary
13:00	**Lunch**

J. Vasquez

14:20	A. Harris: The GDAC Data Product Computation Facility (DPCF)
14:40	H. Kawamura: Japanese research plans towards the satellite/in situ GHRSST-PP network
15:00	G. Wick: In situ and Satellite Data Integration (ISDI). First report of the Technical Advisory Group (ISDI-TAG)
15:20	**Session summary**
15:30	**Coffee break**

>>> Session 3 > Data Access

C. Gentemann

15:50	D. May: NAVOCEAN data and the GHRSST-PP
16:10	M. Petit: The SEASnet program and the GHRSST-PP
16:30	H Kawamura: The NASDA GHRSST-PP data server
16:50	C Donlon: An ESA Category I proposal for access to ESA data within the GHRSST-PP
17:10	**Session summary**
17:20	**Close**
19:30	**Social dinner** (self funded) Enoteca Frascati

December 4th 2003

>>> Session 4 > Validation of GHRSST-PP data products

08:30	C. Gentemann: Calibration and Validation of AMSR-E: Early results	
08:50	P. Minnett: Validation of satellite SST using MAERI data	
09:10	I. Barton, Pearce and Mahoney: Validation of AATSR SST in Australian Waters	
09:30	R. Evans: A comparison of MODIS AQUA and TERRA SST using MAERI and buoy observations	
09:50	L. Horrocks: Validation of ENVISAT AATSR data at the UK Met. Office	
10:10	A. Jessup: Long-term Measurements of Skin and Near-Surface Temperature on the R/V Brown	**I. Barton**
10:30	**Session summary**	
10:40	Coffee break	

>>> Session 5 > GHRSST-PP R&D – Methods

10:50	R. W. Reynolds: OOPC SST Working Group and Buoy Need Requirements	
11:10	J. Vasquez et al.: The Effect of Aerosols and Clouds on the retrieval of SST from AVHRR and ATSR2	
11:30	C. Mutlow: the ATSR Programme – a reference SST data Source?	**G. Wick**
11:50	S. Casitas, P. Le Borgne and H. Roquet: Merged SST data products at Meteo France CMS	
12:10	H. Kawamura: The present status of AMSR-E and ADEOS-II	
12:30	C. Gentemann: Developments in AMSR-E/TRMM-TMI/TRMM-VIRS fusion SST	
12:50	**Session summary**	
13:00	**Lunch**	
14:20	A. Harris: Innovative strategies or cloud removal within the GHRSST-PP	
14:40	C. Gentemann: Diurnal signals in satellite SST measurements	
15:00	P. LeBorgne: Characterising the error in GHRSST-PP data products	**A. Harris**
15:20	C. Merchant: Radiative Transfer modeling limits and using ATSR2 to calibrate GMS.	
15:40	**Session summary**	
15:50	**Coffee break**	

>>> Session 6 > Summary and plenary discussion

16:00	GHRSST-PP Implementation: Outstanding Issues	**C. Donlon**
17:00	AOB	
17:15	**Close**	

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